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A socio-economic analysis of an alleycropping agroforestry system with treated municipal biosolids applied as a fertilizer

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A socio-economic analysis of an alleycropping agroforestry system with treated municipal biosolids applied as a fertilizer

by

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CHAPTER I. INTRODUCTION

According to a recent article in Farm Journal magazine entitled "Suspect Sludge," nearly half of all the municipal sludge, about four million metric tons, produced in this country each year is spread on farmland (Haag, 1992). The United States (U.S.) Environmental Protection Agency's (EPA) proposed Part 503 regulation (a comprehensive plan for the regulation of biosolids treatment/disposal) in the code of federal regulations (40 CFR), however, states that only about 22 percent of all municipal sludge is applied to agricultural land, 30 percent is distributed and marketed, and 40 percent is disposed in sanitary landfills (Goldstein, 1989).

There are growing concerns in the farming community about the land application of sewage sludge (hereafter called biosolids). Haag (1992) cites a few cases where dairy farmers' herds have had outbreaks of arthritis, cases of decreased fertility, and increased numbers of aborted calves. Although the cause of these problems is unclear, it is suggested that heavy metals or chemicals used by U.S. industry, which end up in the municipal biosolids being applied to farmland, might be the cause.

Health-related problems stemming from the utilization of municipal biosolids need to be investigated further. The evidence supporting Haag's (1992) claims is somewhat sketchy. Regardless, the issue of municipal biosolids utilization with minimal environmental impacts and health risks is controversial. The controversial nature is highlighted in Haag's (1992) article by reference to a non-profit organization called "Help for Sewage Victims". When citizen groups are mobilized in response to some perceived environmental problem, there definitely will be more heard about that issue.

In contrast to the message of the Farm Journal article, is the idea that the technology for "cleaning up" biosolids is improving to the point where there may be no need for regulations regarding land application. This point was raised by William Fasth (personal communication, 1992) the program manager of the Forest Soils and Waste Management research program at the University of Washington. His suggestion was that new federal policies may become less restrictive for land application of biosolids. Seemingly, this is because industrial pre-treatment programs, in conjunction with improved sewage treatment technologies, have resulted in "environmentally benign" biosolids. John Ringelestein (personal communication, 1992), the superintendent of the Ames Water Pollution Control Facility, also agreed that waste treatment technologies are improving. He confirmed that, for the City of Ames, the industrial pre-treatment program has substantially reduced heavy metal concentrations.

These two conflicting points of view, "suspect sludge" or "environmentally benign" municipal biosolids, highlight a need to clarify the issues at hand and to evaluate alternative uses, or land application options, for municipal biosolids. As is discussed in this thesis, biosolids are very much a NIMBY (not in my backyard) public nuisance and, because of potential health and environmental risks, its treatment/disposal and utilization is disputed. At the same time, biosolids can provide economic benefits. Thus, there is a real need to consider the issues, and to examine the options for treatment/disposal through the use of a comprehensive decision-making framework.

Renewable Energy Resources

Development of alternative, renewable energy supplies is expected with continued increasing usage of energy. Increasing real costs for fossil fuels, accompanied by a decrease in the supply of these non-renewable resources, will lead to developments of alternative energy sources via market adjustments or displacement of renewable fuel resources for fossil fuels (Skog, 1989 as cited in Twarok, 1990). Biomass for use as a renewable energy source is a possible alternative for agricultural states such as Iowa. With appropriate technologies, biomass can be used for drying corn on the farm, heating residential or public buildings, or producing electricity for municipal facilities. The 1990 Iowa Comprehensive Energy Plan states that biomass for energy is "ripe for development" and can make a considerable impact on the Iowa economy. The Plan indicates that, by using indigenous energy sources, the people of the state will be relieved of the instability of outside control of energy prices (Sibold et al., 1990).

Energy demand is not the only impetus for the development of renewable energy resources. Environmental problems resulting from the use of fossil fuels, create a need for less environmentally degrading energy sources. Development of alternative energy sources will help the state of Iowa to an environmentally clean, more prosperous future (Sibold et al., 1990).

Short rotation woody crops (SRWC) and alleycropping agroforestry for biomass (AAB) production systems are an alternative to the use of fossil fuels. SRWC involves planting fast-growing tree species at relatively close spacing ranging from 0.09 m^2 to about 6 m^2 per tree (Colletti et al., 1991) and rotations, or production cycles, of 1 to 10 years. AAB systems involve combining SRWC systems with agronomic crops in alternating strips. Research scale operations investigating the economic feasibility of SRWC systems for energy suggest that they will be profitable if certain risk factors can be avoided. Difficult to control risks, such as climatic conditions, and insect and disease outbreaks reduce the profitability of the systems. However, in the Pacific Northwest, recent large commercial-scale operations of SRWC systems for fiber suggest that these risks can be averted (See Appendix B). Regardless, SRWC and agroforestry seem to provide other environmental benefits while also providing a stream of renewable energy resources.

Public concern about the environment should stimulate demand for SRWC systems (Twarok, 1990). SRWC and AAB systems provide a variety of ecological benefits. Specifically, the use of woody biomass as a fuel will result in less additions of "new" carbon dioxide (CO_2) to the atmosphere. This is because when fossil fuels are burned, carbon that has been in long term storage is released into the atmosphere. This release of CO_2 is an addition to the current CO_2 balance. Trees, on the other hand, fix carbon from the atmosphere. When burned (or converted to biogas or a liquid biofuel), the woody biomass releases currently cycling (geologic time-scale) CO_2. However, SRWC systems that have reached sustained yield (annual tree biomass growth balances with mortality plus biomass harvest), have the net effect of adding zero CO_2 to the atmosphere (Hall, 1989; Flavin, 1988).

Additional environmental benefits from SRWC and AAB systems may accrue, if these systems are associated with the treatment/disposal of treated municipal biosolids. Because SRWC cropping systems provide year-around cover, surface runoff is reduced. An advantage of AAB systems, is that when either the herbaceous or tree crop is harvested, the other crop would lower erosion potential by providing cover to slow water movement, and reduce wind velocity, thus reducing other problems related to the movement of soil into streams and rivers. When biosolids are applied to an AAB system, the reduction in surface water and sediment flow should reduce concerns for the movement of heavy metals, fertilizers, pesticides, and other pernicious contraries into ground and surface waters.

Added economic benefits could be realized because of increased growth of the trees and crops when the biosolids are used as fertilizer. The economic feasibility of AAB systems is dependent on high yields. In the Pacific Northwest, SRWC yields in field tests range from 17.28 oven-dry metric ton (ODMT) per hectare per year to a maximum observed yield of 47.65 OMDT per hectare per year (as cited in Twarok, 1990). The utilization of biosolids as a fertilizer and soil amendment has been shown to increase tree growth substantially (Johnson et al., 1987; USEPA, 1983; USEPA, 1989). By increasing growth of the woody and herbaceous biomass, the economic competitiveness of an AAB system would be significantly improved. However, Twarok (1990) also found that SRWC systems of silver maple may not be economically competitive given 1) the expected prices for energy, < $40/OMDT, 2) the expected growth of the trees, below 4 OMDT/ha/yr, and 3) current costs of production, > $1000/ha.

The Ames Water Pollution Control Facility and the Ames Agroforestry Project

The new Ames Water Pollution Control Facility (WPCF) began operation in November of 1989. Located approximately eight kilometers south of Ames (see Figure 1), it was the fourth facility to be built by the city since 1904. The impetus for the new facility came when the City received notice from the state regulatory agency of impending and required treatment facility improvements at the 1950 vintage plant located at the intersection of Duff Avenue and U.S. Highway 30.

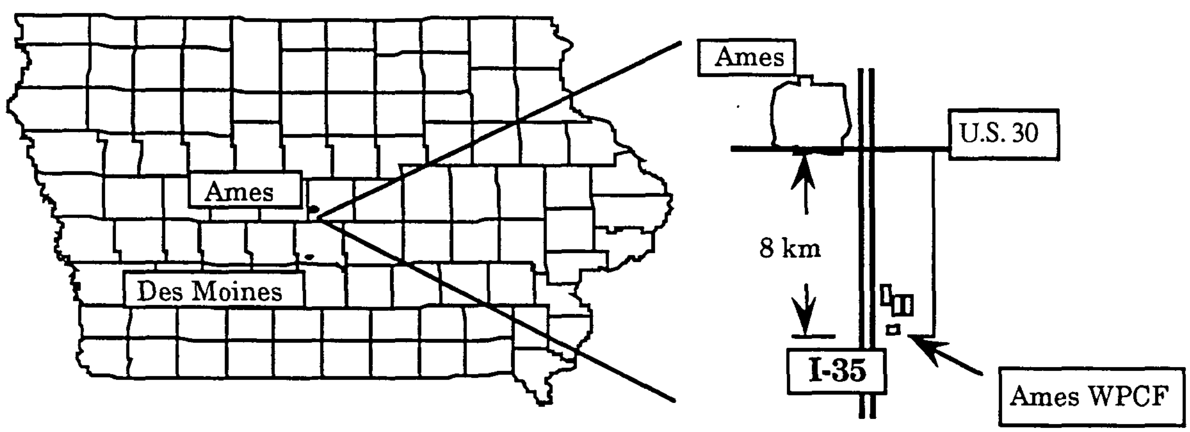

Figure 1. Location of the Ames Water Pollution Control Facility (WPCF) and the Ames Agroforestry Project

The Ames WPCF utilizes physical and biological treatment methods to reduce organic materials, oxygen demand, solids, and ammonia before discharging treated effluent to the Skunk River (Anonymous, 1991).

History of biosolids utilization for the Ames WPCF

Before 1970, the Ames WPCF put the city's biosolids into drying beds after the waste had been treated. Some of these biosolids were land applied in a dry form on city property. However, the majority of the dried biosolids were made available to citizens on a "take-what-you-like" basis. In the early 1970's, before federal regulations were in place, the city shifted to land application in combination with a "ponding method." Ringelestein (1992) cited that this system used an irrigation line that was run from the 1950 WPCF to adjacent crop fields. Biosolids, which were ~95% water, were pumped to those fields where ponds formed. The ponds were then allowed to dry, and if farming occurred on those fields, the biosolids would be worked into the soil. With the passing of the Clean Water Act of 1972, the WPCF began land applying most of its biosolids. Surface application was allowed on the upland sites out of the floodplains, and injection was required within the floodplain. Further, there were limits placed on the quantities of biosolids placed on lands.

Description of the Ames Agroforestry Project

It seems that the current public attitude toward the treatment/disposal of municipal waste is to limit the land application of biosolids. There have been some forecasts saying that disposing of municipal waste on food-chain crops will become very restricted and quantities allowed to be applied very limited. However, current literature discussing biosolids regulations are not clear on regulatory trends. In any case, because of public attitudes and the possible limitation for the land application of municipal biosolids, the City of Ames initiated a project to investigate the feasibility of a treatment/disposal system utilizing non-food chain crops (Ringelestein, 1992).

The cropping system that has been established is utilizing a combination of agronomic crops and trees in an "alleycropping agroforestry for biomass" system - the AAB system. Both the trees and herbaceous crops will be used for biomass for conversion to electricity through a gasification process. The primary goal of this project is to investigate whether or not an AAB system can a provide a cost-effective biosolids treatment/disposal method for the municipality. The Ames Agroforestry Project (AAP) was initiated to prepare for anticipated changes in federal regulations eliminating the land application of municipal biosolids to agronomic food-chain crops. WPCF managers approached scientists at Iowa State University (ISU) to develop a SRWC alternative that would meet the goals of the WPCF managers, and the community of Ames. The ISU researchers decided to combine trees and herbaceous crops and, in short, "the system is designed to be cost effective, environmentally benign, and provide net benefits to the community and its citizens" (Schultz et al., 1991).

The AAP is an interdisciplinary project involving scientists with backgrounds in forestry, ecology, economics, extension, genetics, geology, hydrology, soils, physiology, mechanical engineering, and biometrics. Other cooperators on the project are the Ames WPCF engineers, and environmental protection and energy personnel from the Iowa Department of Natural Resources (IDNR) (Schultz et. al., 1991).

The project is a special alleycropping system of herbaceous crops and trees which will provide an alternative energy resource at harvest. Because the system consists of alternating strips of agronomic crops and trees, both plant systems will contribute to the expected benefits. The tree crop benefits the agricultural crop by reducing losses in soil and plant moisture and increasing boundary layer CO_2 as a result of wind reduction, while the shorter agricultural crops allow more sunlight to reach trees along the edges of the strip, thereby increasing productivity. The agronomic crops used in this project have been specifically selected because of the potential for biofuel production and because they are generally not food chain crops (Schultz et al., 1991).

Objectives of the Ames Agroforestry Project

The project objectives are (Schultz et al., 1991):

1) to study the interactions between the biosolids, the herbaceous and woody plants, and the soils in terms of the movement and use of the macro nutrients nitrogen, phosphorous, and potassium - and the fate and transformation of heavy metals, such as cadmium, lead, copper, zinc, etc.;
2) to determine the expected increase in productivity of the herbaceous and tree crops;
3) to determine the movement of nitrogen and heavy metals in the surface and groundwater;
4) to demonstrate the conversion of the biomass to biofuels for use on-site by the WPCF; and
5) to evaluate the costs and benefits of the system.

Project design and implementation

Alternating rows of trees and crops are planted in a north-south orientation (Figure 2). The corridors of trees consist of six rows of a cottonwood hybrid (*Populus x euramericana* - clone NC-5326) planted in three sets of

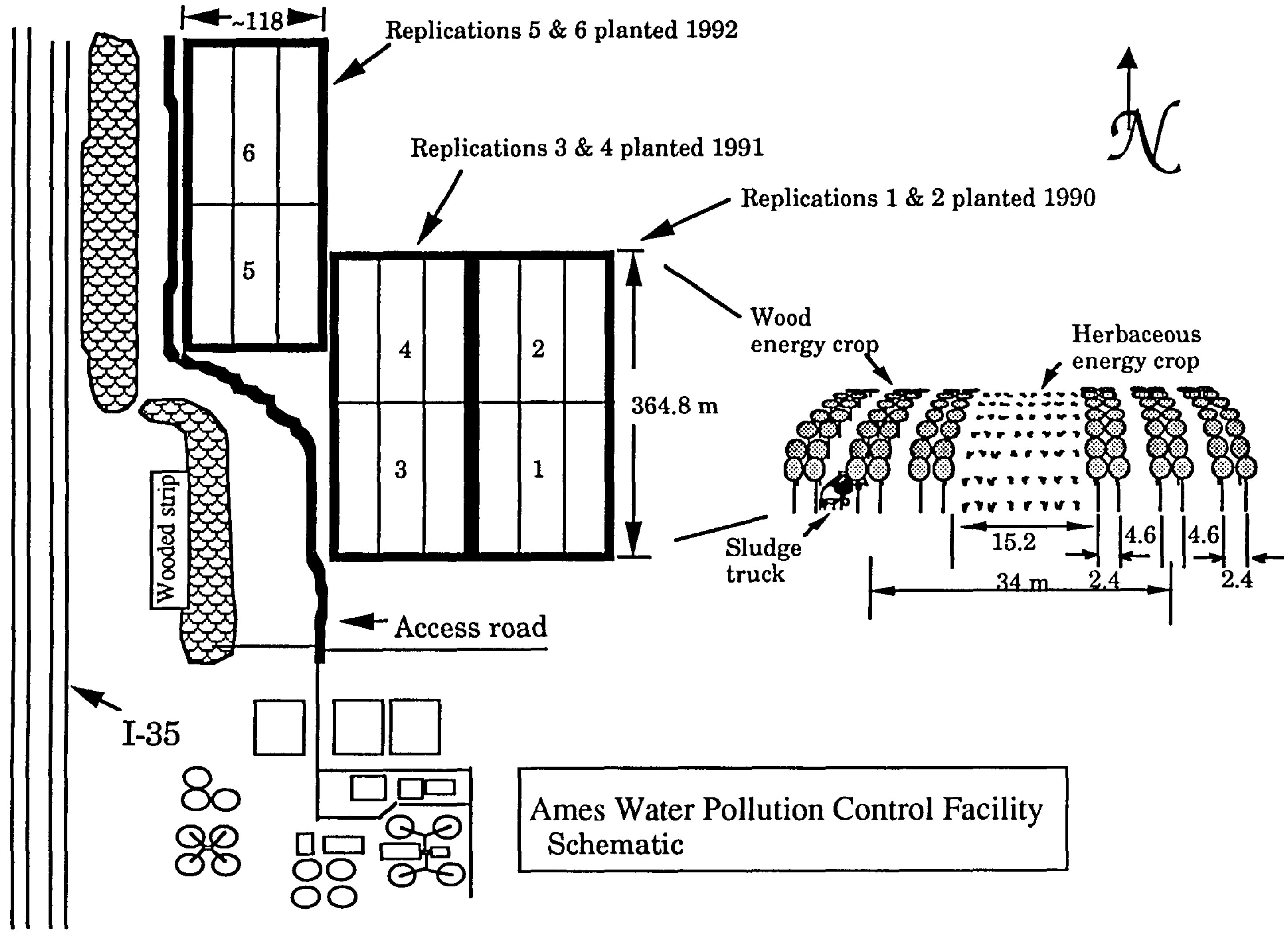

Figure 2. General layout and location of the Ames Agroforestry Project. Replications 1-6 total approximately 12 hectares. Distances in meters, not drawn to scale.

closely spaced rows. Spacing between tree rows is 2.4 m and 4.6 m between double row sets (see Figure 2). The wider spacing allows access for the biosolids application vehicle. Trees will be harvested on a 6 - 8 year rotation, depending on growth (Schultz et al., 1991).

The herbaceous crop strips that separate the tree strips are 15.2 m wide. For each replication, there are three tree strips and three herbaceous strips. Originally, switchgrass, crambe, and a double crop of forage sorghum and rye were planted when the project was established in 1990. The performance of the crambe and the double cropping system was less than desirable. Thus, in 1991, switchgrass and a single crop of sweet sorghum were used. Sweet sorghum was chosen for its high biomass production potential. For 1992, the switchgrass and sweet sorghum are still being used, but an additional "high productivity" tropical corn (carribean corn hybrid) has been established. The perennial switchgrass is harvested in July and October (Schultz et al., 1991).

The biosolids application rates are based on nitrogen content of the biosolids, which is approximately 2% by volume. These rates are: none (zero application of biosolids, the control treatment), 1X (normal is set at 168 kilograms (kg) of total nitrogen per hectare per year and is based on the apparent annual uptake of nitrogen by both agronomic and tree crops), and 2X. Biosolids are surface applied to the trees and switchgrass in spring and fall as per special permit from the IDNR. For the other crops, it is injected into the soil before they are planted.

Biosolids were first applied in the late spring of 1991. A total of six replications have been established with plantings in 1990, 1991, and 1992 . The project design is a randomized block design for statistical analysis (Schultz et al., 1991). As of May 1992, the total project size is about 12 hectares (ha) with all trees and crops planted.

A gasifier was obtained from the IDNR for the production of low-British Thermal Units (BTU) biogas. It will use the biomass from the trees and crops as feedstock. Currently, the gasifier is located at the old Ames WPCF and is being tested with a diesel generator. It is expected that the gasifier will be moved to the new WPCF within the next year or two.

Biosolids treatment/disposal options for Iowa municipalities are extremely limited. Land application or municipal landfills seem to be the only choices for biosolids treatment/disposal given the small size of many Iowa communities. For Ames, the only realistic option is land application since the establishment of the solid waste recovery plant and subsequent closing of the city landfill. The only other option would be to construct a hazardous waste disposal landfill. However, this option is not appealing to the WPCF managers primarily because of the high cost of such endeavors (Ringelestein, 1992). Economic constraints limit the opportunities for technological innovation for treatment/disposal of treated municipal biosolids. On the other hand, innovations in land treatment/disposal would be expected because of the availability of easily accessible land.

Applying biosolids to an AAB system for the land utilization of municipal waste is a unique undertaking. Published research indicates the technological and ecological feasibility of the AAB system is sound in terms of producing biomass (Reynolds and Cole, 1981; Johnson et al., 1987; USEPA, 1983; USEPA, 1989). However, research results are lacking concerning the land application of biosolids to AAB systems. The Ames Agroforestry Project may be an effective and efficient alternative for the utilization of municipal biosolids. However; there are still several possible hurdles before the system becomes widely accepted. Those hurdles include, but are not limited to:

1) the economic feasibility of the treatment method;
2) concerns for ecological impacts;
3) whether the project fits the political/institutional framework of the community.
4) social concerns related to health and other issues; and

CHAPTER II. LITERATURE REVIEW

Because of potential health and environmental risks associated with improper disposal of municipal biosolids, there should be a method for evaluating treatment/disposal alternatives, giving consideration to the political and social aspects of a community, and the environmental impacts of each alternative. Equally important in this evaluation is the need to determine the economic feasibility of biosolids treatment/disposal alternatives.

In other words, this thesis will address "impacts" resulting from a decision made regarding the treatment/disposal of municipal biosolids in a given manner. The potential impacts suggest a need for the development of a decision-making model to evaluate biosolids treatment/disposal. The decision-making model will be applied to the City of Ames situation which will include an alleycropping agroforestry for biomass (AAB) system. These "impacts" are classified as economic, ecological, political/institutional, and social.

Overview of Municipal Biosolids Treatment/disposal

Since the passing of the Clean Water Act of 1972, municipalities have been required to cleanse their wastewaters before discharging them into the environment. Treated municipal biosolids are the by-product of the wastewater treatment process.

There are five federally accepted and approved treatment/disposal methods for biosolids: 1) land application, 2) distribution and marketing, 3) landfilling, 4) incineration, and 5) ocean disposal (USEPA, 1989). Land application is considered an extension of the treatment process through the use of the living plant and soil system for additional biological breakdown of biosolids. Disposal, on the other hand, is simply and out-of-sight, out-of-mind dump of biosolids - this is the case with landfill disposal. Each method is most often associated with specific geographical locations or size of municipality. For example, ocean disposal would be used most commonly by municipalities located near the ocean. Incineration, on the other hand, is only a viable option for those municipalities large enough to afford the capital investment necessary to purchase the expensive equipment for burning biosolids in a manner which satisfies clean air regulations. In Iowa, given the relatively small population with many rural communities and a well-developed agricultural sector, a common method for treatment/disposal of biosolids is land application.

Land application of municipal biosolids

To determine which biosolids utilization option to use, municipalities must consider several criteria. The EPA Process Design Manual entitled "Land Application of Municipal Sludge" (1983) provides the most recent governmental information for the development of a land application program for biosolids treatment/disposal. Other publications also provide guidelines for developing waste management strategies. One apparent weakness of federal regulation of biosolids treatment/disposal, is that site-specific information for a particular region is limited. This is because different sites have different soil types, climatic conditions, and different crops that are grown; thus, comprehensive guidelines and regulations covering all these variables must, by necessity, be generalized (Goldstein, 1989).

Current regulations, established in 1979, require that biosolids be treated by a "process to significantly reduce pathogens" prior to land application (as cited in Younos et al, 1987). Standard treatment processes such as anaerobic digestion, aerobic digestion, air drying for at least three months, composting, and lime stabilization are considered satisfactory to meet these requirements. Because biosolids generally are not entirely biodegraded by these processes, public access to biosolids applied land is restricted for twelve months after application (USEPA, 1989).

Biosolids can be categorized as having different qualities depending on the treatment processes used. Characteristics such as water content, degree of stabilization, and pH are important factors to consider when developing a biosolids land application program. Content of water will determine transportation costs and method of application. Degree of stabilization refers to biodegradability and odor potential. And, pH is important for the characterization of heavy metal leachate from the soil and metal uptake by crops (Younos et al., 1987).

Important constituents of biosolids for land application purposes are: nutrients (N, P, K), metals, pathogens, organic matter, and toxic organic chemicals (USEPA, 1989). These factors will determine whether the biosolids can be used in a land application program and the kind of application method used.

In the United States, biosolids are usually land applied in four settings: 1) on agricultural lands, 2) forest lands, 3) on drastically disturbed lands, or 4) on land dedicated to biosolids disposal (LDSD). In all types of treatment/disposal settings, except LDSD sites, biosolids are a resource which act to improve the characteristics of the soil. Biosolids act as a soil conditioner by facilitating nutrient uptake, increasing water retention, permitting easier root penetration, and improving soil structure which in turn reduces runoff and erosion and makes the soil easier to work (USEPA, 1989). In the agricultural setting, biosolids can serve also as a partial replacement for expensive chemical fertilizers. Biosolids contain nitrogen, phosphorous, small amounts of potassium, and other trace elements required by plants. Although these nutrients are not usually found in optimal proportions, application of appropriate quantities of biosolids can meet most or all of the fertilizer needs of certain crops (Ringelestein, 1992; USEPA, 1983). Based on 1983 fertilizer prices in the South Central United States, a metric ton of dry biosolids would contain approximately $9.08 worth of nitrogen, $28.33 worth of phosphorous, and $0.66 worth of potassium (USEPA, 1989).

Application of biosolids to agricultural land This method for treatment/disposal of municipal biosolids has been used since man discovered the fertilizer benefits of human waste (Pahren, 1980). Bitton et al. (1980) point out that land application is a supplemental treatment for municipal wastes. This is because removing all "pernicious contraries" from the biosolids would be very expensive. At present, land application of biosolids is a logical alternative because of its environmental and economic advantages over other methods (Younos, 1987). Because technologies for the most effective sewage treatment are both capital- and energy-intensive, land application of biosolids is a preferable alternative (Bitton et al., 1980; Jacobs, 1981)

As mentioned, application of municipal wastes to agricultural land in Iowa is common and, because of environmental and economic incentives, it seems to be a reasonable option. Because the term "disposal" carries a negative connotation, applying biosolids to agricultural land should be viewed as "treatment", "recycling" or "utilization" of a waste material (Jacobs, 1981). This point is important considering the difficult challenges for municipalities in dealing with the public reaction to the idea of land application of biosolids to agricultural crops.

The U.S. EPA has set specific limits on the amount of biosolids that can be applied on agricultural land. Currently, these limits are determined by a plant's ability to take up nitrogen and/or phosphorous. These rates are referred to as "agronomic rates" (USEPA, 1983). As mentioned, public access to biosolids-amended land is restricted for at least twelve months after application. However, crops grown for direct human consumption are a special case. If there is direct contact between the biosolids and the edible portion of a crop grown for human consumption, federal regulations require that at least an eighteen-month period must elapse between biosolids application and growing of such crops, or that the biosolids be subjected to further disinfection treatment prior to application. Disinfection treatment processes may include composting, heat drying, heat treatment, thermophilic aerobic digestion, pasteurization, and irradiation (Youmo et al., 1987)

The utilization of biosolids on agronomic crops offers a number of advantages. Because of the nutrient value of the biosolids, using it as a fertilizer has economic and resource conservation incentives. Specifically, the citizens of a community will receive direct benefit if the municipality uses the biosolids as fertilizer on public lands, and indirect benefits if used on private lands. The idea of "recycling" the nutrients is appealing to those citizens concerned with resource conservation. In many cases, a major advantage for this treatment/disposal method is the municipality not having to buy land. A final advantage is that, because application sites for agronomic use are normally rural, potential complaints about land utilization can be minimized (USEPA, 1983).

Disadvantages for agronomic utilization are primarily associated with the heavy metals, pathogens, and toxic organic compounds that can be contained in biosolids. There is a potential for harm to plants taking up the elements (phytotoxicity), and also health risks for humans or animals that consume the crops (Dacre, 1980; Yeager, 1980). These problems limit the biosolids application rates, and also impact the timing of application (USEPA, 1983).

Application of biosolids to forested lands Application of biosolids to forested land is a relatively new utilization of municipal biosolids. As with agronomic applications, there are advantages and disadvantages to this utilization method. One of the more significant advantages of biosolids application to forest land is the fertilizer effect. Increased tree growth is a nearly universal effect of biosolids application in the forest (Brockway, 1988). Incredible variation in increased height and diameter growth has been reported. Height growth increases have been reported to vary from 23% to 1,190%, whereas diameter growth increases are reported to vary from 36% to 1,250% (USEPA, 1983; Johnson et al., 1987; USEPA, 1989). Variability in growth depends on several factors including tree species, site quality, biosolids quality, and application rates. Biosolids were found also to produce greater quantities of above ground biomass in hybrid poplar than when commercial fertilizers were used (Johnson et al., 1987).

Biosolids act also as a soil conditioner for forest soils. Because biosolids contain organic matter, the permeability of fine textured soils is improved. For clay soils, for instance, the biosolids will increase the soil's water holding capacity (USEPA, 1983).

Unlike agricultural settings, forests do not produce a food crop for humans. As a result, there are fewer health concerns associated with this utilization practice (USEPA, 1983; USEPA, 1989). Another benefit, which primarily benefits water pollution control facility (WPCF) operators, is that forests are a perennial entity allowing scheduling of biosolids applications to be less complex than use with agronomic crops where timing is determined by planting and harvesting schedules. A final advantage of forest utilization of biosolids is that it is not necessary for the municipalities to purchase land for the land treatment of biosolids (USEPA, 1983).

Disadvantages for the application of biosolids to forest land are fewer than those for agronomic crops. One limitation of increased use of this practice is the limited number of municipalities using this treatment method. This "limited information" would require greater effort for WPCF operators to overcome the "gap" of information, depending on their region, to start a forest land biosolids application program (USEPA, 1983).. Nevertheless, considerable research is underway nationwide dealing with the application of biosolids to forest land.

Public access is another potential disadvantage to forest land biosolids utilization. In regions where forests are open to the public, it would be difficult to control access following the application of biosolids. In Iowa, however, this may not be as critical because most of the land is privately owned.

The final limitation for forest utilization of biosolids is associated with access for biosolids application vehicles. Primarily associated with well-established forests, this problem is dealt with by building access roads or by using specially designed biosolids application vehicles for application. In Washington, the cities of Seattle and Tacoma use a water cannon (similar to a fire hose) to spray the biosolids up to 150 feet into the forest. This application method does not require a special vehicle to enter the forest, but some access roads are necessary (USEPA, 1983; USEPA, 1989). For forest plantations, this problem can be eliminated by designing the plantation with "alleys" for the biosolids application vehicle to move throughout the plantation (see Figure 2) or by the use of irrigation lines.

Energy and Renewable Resources

Half of all developing countries rely on imported oil for 75 percent of their commercial energy needs. This dependency puts these major economies in precarious positions where they can be thrown into economic collapse at the whims of an oil cartel, as was the case of the Arab oil embargos of 1973-74 (Shea, 1988).

Determining the real cost of using fossil fuels is a multifaceted task. When pumping gasoline or filling our municipal utility storage bin with coal, it seems reasonable that the prices paid reflect all costs of production and utilization. This is not the case with fossil fuels. Hubbard (1991) points out that hidden costs of energy include tax credits, environmental degradation, increased health care costs, and lost employment. Estimates for these hidden costs in the U.S. alone range from $100 billion to $300 billion per year. Called externalities by economists, many of these extra costs are nearly impossible to quantify with any degree of accuracy because of the complexity of the issues as they relate to social and environmental impacts. Unfortunately, as pointed out by Hubbard (1991), conventional economics and current market policy ignore externalities, essentially setting their cost at zero.

Economists are making attempts and a variety of methods are developing to measure these extra costs. However, difficulty arises when one tries to put a dollar value on a human life, or determine a specific value associated with damage to the environment. Or, on the other hand, to even determine what damage has been done.

Non-renewable energy sources have a distinct negative attribute because some day they will be gone. The other most identifiable problems with burning fossil fuels are related to environmental degradation. Air pollution in the form of acid rain and increasing atmospheric CO_2 are the two most commonly recognized negative impacts from burning coal and oil. Impacts from both of these energy sources are considerable. Brown and Flavin (1988) suggest that the acid rain problem has substantially damaged the forests in Europe, citing that, as of 1986, some 30.7 million hectares (an area equaling the size of West Germany) had been affected. Brown and Flavin (1988) suggest also that additions of CO_2 to the atmosphere contribute up to 50% to the global warming problem.

Public awareness for environmental problems has increased dramatically in the past few decades. This awareness provides the impetus for the use of more renewable energy resources; however, existing policies supporting non-renewable energy are entrenched and will have to be uprooted to advance toward a more sustainable energy supply future. This support, in part, needs to come in the form of subsidies and funding for research and development for renewables, including biofuels.

Hubbard (1991) points out that the U.S. government provides about $50 billion per year to energy producers as tax credits and funding for research. Of these dollars, $26 billion goes to fossil fuels, $19 billion subsidizes nuclear power, and $5 billion supports renewable energy. The support for renewable energy is for all forms including solar, wind, geothermal, and biomass for energy. The imbalance in these funding priorities is exacerbated further by the fact that the investment for renewable sources provides 8 percent of the energy used in the U.S., whereas the investment in nuclear power provides only 7 percent of the energy consumption.

This allocation is questionable, not only from an economic standpoint, but also for the development of a sustainable energy future. Currently, it is necessary for promoters of solar, wind, or biomass for energy to show market competitiveness with the other highly subsidized non-renewable (fossil and nuclear) energy sources.

Biomass is an alternative energy source. It is probably the oldest and most fundamental form of renewable energy. It can be produced repeatedly in a relatively short period of time by converting the sun's energy to chemical energy through the photosynthetic process (Lawlor, 1991). Flavin (1988) indicated that planting trees can also help restore balance to the current carbon cycle by transferring carbon from the atmosphere to terrestrial systems. When combined with other cover crops, additional environmental benefits can be afforded in the form of reduced soil erosion, and control of surface and groundwater contamination. Further, combinations of crops and trees also can be grown on more marginal lands, where the production of food crops would be less viable. However, exact matching needs to take place between species, soil type, and management levels before energy crop production can be cost effective (Wright, 1990).

Potential biomass production from trees

In the world today, wood is used for energy more than for any other use. In fact, the final end use for most timber in the U.S. is fuel energy (Koning and Skog, 1987).

The feasibility of using wood for energy is demonstrated by the fact that, between 1972 and 1984, the U.S. pulp and paper industry has reduced its usage of oil by 50% through the use of wood for energy, while production of pulp and paper has increased (Koning and Skog, 1987). Using two wood energy consumption projection models, Skog (1989) determined that the use of fuelwood by industrial/commercial and residential consumers will increase from 1.3-1.5 Quads (5.2-6.1 billion cubic feet) in 1986 to 2.2 Quads (8.8 billion cubic feet) by 2020.

Koning and Skog (1987) suggested that new fuelwood markets could be initiated by thinning small, private woodlots of less desirable species of trees. In their scenario, small cooperatives could be established where the biomass fuel could be prepared and distributed to local markets.

Another method for producing fuelwood is the establishment of short-rotation, woody crop (SRWC) plantations. Because of the relatively high inputs required to increase productivity, the economic feasibility of SRWC for energy will be influenced significantly by the production costs and price for energy (Rose, 1975). Twarok (1990) determined that a SRWC system growing silver maple was not economically feasible, primarily because of high cost of land rent, site clearing and preparation, planting, harvesting, and the low expected price for energy.

However, when Twarok (1990) considered the introduction of improved production and harvesting technologies, or subsidies from the government, the economic feasibility of SRWC systems improved considerably. Additionally, Twarok's (1990) analysis did not include the use of fertilizers to improve plantation productivity which will occur when biosolids are applied.

Johnson et al. (1987) conducted experiments comparing the growth response of four poplar clones to the application of commercial fertilizer or municipal biosolids on marginally productive lands in New York.. They found that the application of biosolids increased the growth of the trees from 6% to 40% depending on application rate and clonal species. On the other hand, they found that commercial fertilizers did not improve growth of the trees at all.

Potential biomass production from herbaceous crops

Herbaceous crops grown for increased production of biomass have shown high productivity similar to fast-growing trees. An advantage of growing herbaceous crops in Iowa, is that traditional farming equipment can be used for production and harvesting (Bransby et al., 1990). Also, marginally productive lands can be converted into producing substantial biomass while reducing soil erosion which, is a serious problem when grain crops are grown on these lands (Cherney, et al., 1990). This can be done if perennial crops (e.g., switchgrass) or double crops (e.g., forage sorghum and rye) are grown.

Yields from studies conducted by the Agronomy & Agricultural Engineering Research Center, ISU, Ames, Iowa, showed annual average yields of 10 metric-tons/ha for switchgrass and 17 metric-tons/ha for sweet sorghum (Anderson et al., 1992).

Switchgrass has the advantage over grain crops because it can be very productive on marginal lands where it might be difficult to plant grain crops year after year because of slope or other reasons. In other words, it can be planted on marginal lands not suited well for grain crop production.

The potential for tremendous biomass production from forage crops is evident; however, energy products from the crops are not as promising. In most cases, the crops are being produced for conversion into ethanol. Problems arise in this regard because economically viable processing still needs to be researched (Bransby et al., 1990). Sorghum, like sugar cane, can be converted into ethanol through a simple process of crushing, and fermentation (Dovring, 1988).

For the Ames Agroforestry Project (AAP), additional difficulties are likely because the woody and herbaceous biomass is to be converted to a low-BTU biogas via the utilization of a gasifier. And, herbaceous crops have not been found to work as well in gasifiers as wood. However, the potential efficiency of gasification processes can reach 70% (Parker and Roberts, 1985), and there might be some optimal mixture of herbaceous and tree biomass that will perform adequately.

Systems Analysis and Environmental Assessments

Quade (1968) defined systems analysis (SA) as "... a research strategy, a practical philosophy of how best to aid a decision-maker with complex problems of choice under uncertainty." Quade goes on to say that SA is a "systematic" means to consider a "full problem," to develop objectives and alternatives, and compare them in the light of their consequences. One important aspect of SA is that intuition plays a critical role in the development of the analysis (Quade, 1968)

The environmental assessment (EA) process as sanctioned by the EPA is related to SA. The EA process is designed to produce a concise document to achieve the following purposes: to provide sufficient evidence and analysis for determining whether to prepare an Environmental Impact Statement (EIS); to aid an agency's compliance with the National Environmental Protection Act of 1969 (NEPA) when no EIS is necessary; and when found to be needed, to facilitate preparation of an EIS. In general, an EA is preliminary to the preparation of an EIS and is to include a brief overview of impacts of a proposed action (Schoenbaum and Rosenberg, 1991). Each EA or EIS is a systematic attempt to quantify impacts, and benefits and costs from a specific alternative.

The EA and EIS processes are required when federal agencies plan actions that would result in some change or impact on the natural or human environment. Specifically the result of federal legislative action, these documents are intended to be "action forcing" so that the policies and goals of NEPA will be infused into actions taken by federal agencies. Schoenbaum and Rosenberg (1991) further stated that , an EIS "... must provide full and fair discussion of significant environmental impacts and shall inform decision-makers and the public of the reasonable alternative that would avoid or minimize adverse impacts or enhance the quality of the human environment."

Environmental Impact Assessment (EIA) is a final analysis process and is very similar to EA and EIS. As mentioned, the EA and EIS have specific roles and meaning in federal actions. Similarly, several states have developed regulations requiring some type of impact statements which are designed to analyze the overall impacts of some specific governmental action.

Considerable literature is available discussing the EIA process (Wathern, 1988; Warden and Dagodag, 1976). For this thesis, the technique being used for analysis is best described as a mini-EIA. This definition is appropriate because the analysis is to be comprehensive and interdisciplinary. However, the analysis is being completed by one person, which, as outlined by NEPA, would be insufficient for an EIS.

The "EIA process" has been chosen as a methodology of analysis because of its versatility. The EPA was excused by NEPA from preparing EIS's except for providing funding for construction grants (Moss, 1977). This exception specifically applies to construction grants including those provided to municipalities for WPCF construction. This means that before municipalities can receive funding for building a WPCF and EIS must be prepared. However, according to the Natural Resources Defense Council only sixty-five out of four thousand impact statements had been prepared for WPCF grants by 1974 (Moss, 1977).

Federal regulations pertaining to land application of biosolids are covered primarily in 40 CFR 257 - Criteria for Classification of Solid Waste Disposal Facilities and Practices (USEPA, 1989). Currently, the EPA is working on the Part 503 regulations, which will be the "first comprehensive rule for sludge" as stated by Dr. Alan Rubin of the EPA (Goldstein, 1989). The Part 503 rules were to be out in 1990; however, after being made available for public comment, controversy over the 3000+ page document has delayed its release. And, it is not clear when the 503 regulations will be made official (Goldstein, 1989).

This discussion leads into the problem regarding the handling of municipal treated biosolids. Given the ubiquitous nature of municipal waste, there are serious concerns regarding land application that are much more extensive than what can be covered by a set of regulations limiting organic or inorganic substances. At this time, the 40 CFR-257 are the guidelines that have been set by the EPA, enforced by state agencies, to regulate treatment/disposal of municipal biosolids. Increasing concerns for the use of biosolids related to health risks for people, and damage to the environment are real. Processing, pre-treatment, and other waste handling concerns are important issues, which are given substantial consideration by plant operators and regulatory agencies. Similar considerations should be given to the treatment/disposal of the biosolids - the by-product of the treatment process. This is because biosolids tend to be concentration of the most unwanted materials from the sewage treatment process (Dacre, 1980).

A lack of consideration by municipalities for the treatment/disposal of biosolids is highlighted by Canter's (1979) evaluation of 28 draft or final EIS's prepared for wastewater facility plans from mid-1976 through the fall of 1977. Surprisingly, these 28 EIS represented 15% of all EIS's prepared for the 11,000 grants that had been awarded by August of 1977. In his review, Canter found that 22 of the 28 EIS's described biosolids treatment/disposal options; however, only four considered environmental impacts resulting from these options. In Canter's (1979) opinion, this was a key deficiency of EIS's prepared on WPCF plans.

In the 1983 EPA manual entitled "Land Application of Municipal Sludge," it is suggested that WPCF managers approach the issue of obtaining lands for biosolids treatment/disposal with a “low profile." Given today's explosion of environmental concern by the general public and public involvement in governmental actions, this method probably will result only in controversy. Performing some type of analysis of biosolids treatment/disposal options will soon be a necessity so that municipalities can avoid conflict. As pointed out by Wathern (1988), the rewards reaped from investing in the EIA process more than pays for the trouble of investigation. In addition, once a system for analysis is in place, the effort required for subsequent analysis is reduced substantially.

Wathern (1988) suggested that the EIA process works best with the efforts of several people. In fact, NEPA and the Council for Environmental Quality (CEQ) specify that for federal actions the "interdisciplinary team" is the single most important component of the EIS process (Black, 1981).

Although an EIS is intended to provide legal protection for a governmental action, the same document can provide valuable information in other areas of decision. The process may reveal other alternatives for achieving the project objectives with less environmental disruption (Wathern, 1988).

Economic considerations

Economics is the "acid test" for the development of biosolids treatment/disposal alternatives which might be considered feasible for municipalities (Ringelestein, 1992). Serious questions arise concerning long- and short-term economics, especially related to environmental costs associated with the treatment/disposal of "pernicious contraries." Is it more economical to treat/dispose of the biosolids now in the most environmentally safe manner? Should we pass those costs on to future generations? It seems sensible that a compromise be reached and methods can be developed to provide reasonably safe economical treatment/disposal now, while defraying most of the external costs that would likely be a burden for future generations.

The most difficult task, which is beyond the scope of this thesis, is to determine how much it will cost to clean up the mess we leave behind today. In the past, it was normal procedure to externalize the environmental costs and pass them on to society. These practices are becoming less common due to the increasing environmental consciousness in society. And, as a result, more of these costs will be put back on to those entities that are doing the polluting. Ultimately, it will be necessary for communities who generate the wastes to support the increased expenditures for more safe treatment/disposal of biosolids.

The primary economic question to be addressed in this report is whether the Ames Agroforestry Project is cost effective given the expected biomass energy output of the system, as well as, to compare the AAB system to the current land application program being used by the City of Ames. It is also important to look at direct and indirect environmental costs and benefits. It will be much more difficult, however, to place dollar values on these items.

Typically, biosolids are perceived as a bad thing. It is the stuff that is left over after you clean the water. What is usually ignored, except by farmers and those close to the waste-water treatment industry, is that there is a real value associated with biosolids in the form of nitrogen and other macro-nutrients. The nitrogen value of municipal biosolids can be quantified by the commercial fertilizer cost forgone as a result of using the biosolids. Another benefit is the environmental costs avoided by not having to produce nitrogen commercially. As the market price of commercial fertilizers increases, the economic value of biosolids will increase (Pahren, 1980; Bultena, 1992).

Ecological considerations

Concerns for the natural environment regarding the land application of municipal biosolids arise in relation to soil, water, plants, and animals. Currently, for the Ames Agroforestry Project, these ecological considerations are being given priority. This is because information about the ecological impact of land-applied biosolids to an agroforestry system is limited.

Ultimately, the investigation and discussion of the scientific and technical concerns for each of these areas could be a very extensive endeavor.

The EPA (1983) manual for the land application of municipal biosolids discusses the impacts of land application of biosolids on soils and plants. Characterization of soil is a complex process even without considering the changes resulting from the introduction of biosolids. The impacts on plants is similarly complex, as is monitoring water. Any attempt to discuss technical aspects about any of these concerns is beyond the scope of this methodological analysis. Determination of negative impacts in these areas is best left to the scientists and technicians who are experts in these fields. To highlight the complexity of ecological interactions, Figure 3 depicts a simplified diagram of the possible pathways for transformation of inorganics in soil.

The EPA and state regulatory agencies like the IDNR set out regulations governing the loading rates of heavy metals acceptable in soils and plants. However, these guidelines are likely to change with the release of the new Part 503 regulations.

Studies of nitrate accumulation in biosolids-amended soils were conducted by Higgins et al. (1982). The studies indicate that with an increase in the rate of biosolids application there was a subsequent increase in organic-N in soils. The depth of the accumulation depended on the time between application and time of measurement.

Nitrogen is related also to water contamination. The Ames Agroforestry Project has an extensive groundwater monitoring component, to observe the movement of heavy metals, nitrogen, and other identifiable chemicals that

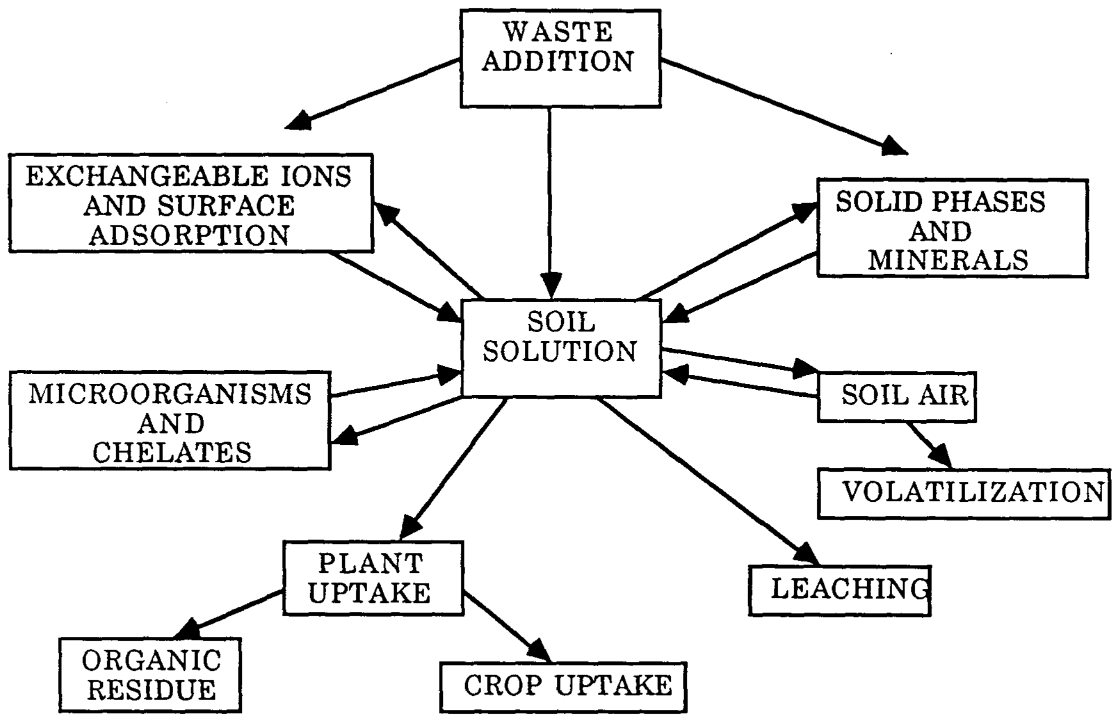

Figure 3. Transformation of inorganics in soil from Ryan, 1977

might move into and through the groundwater. The study of water is as complex as are the other ecological concerns.

For Iowa, the publics' concern regarding groundwater protection is embodied in the Iowa Groundwater Protection Act of 1987. The Act is one of the most progressive pieces of legislation for the protection of a natural resource in the U. S. However, the emphasis of the Act is not on regulation but on education and information in an effort to reduce Iowa's groundwater pollution problem (Hallberg et al., 1987).

The concern for water contamination resulting from the utilization of biosolids on land is justifiable. Higgins et al. (1982) found that groundwater conductivity was significantly affected by application of biosolids at rates of 22.4 metric tons per hectare (mt/ha) and 44.8 mt/ha. At these two rates, six months after application, signs of contamination occurred. In addition, there was a significant correlation between level of contamination and rate of biosolids application. When biosolids application ceased, the contamination also declined. Nitrogen in groundwater increased with the land application of biosolids. With higher rates of biosolids being applied to land, higher levels of nitrates were observed in the groundwater (Higgins et al., 1982).

The impacts on animals grazing on biosolids amended land, or having contact with biosolids, also is a concern (Kienholz, 1980). Cattle, swine, rats, baby chicks, and earthworms were studied for effects from interaction with biosolids. No specific trends were found in studies reviewed by Kienholz (1980). The complexity in this research arises when considering the number of variables that can occur. Different impacts on different animals can be seen to depend on the type of interaction (ingestion, physical contact), the quantity of biosolids coming in contact with the animals, and the duration of the contact. Negative impacts on animals do occur, but they are highly dependent on the situation (Kienholz, 1980; Haag, 1992). Impacts on domestic and non-domestic animals need to be studied further and likewise given consideration when making decisions regarding alternatives for the land application of biosolids.

Impacts on plants are a concern as well. Phytotoxicity in plants has been shown to be caused by elevated soil concentrations of zinc and copper in conjunction with an acidic pH and growth of metal-sensitive crops such as vegetables. Application of biosolids with low metal content at recommended plant/nutrient utilization rates shows minimal problems with phytotoxicity (Sommers, 1980).

Research of application of biosolids to forest lands has been underway for several years at the Pack Forest (University of Washington). Studies have been conducted examining the impact of different biosolids application rates on forested lands. It has been found that metal accumulation depends on species, biosolids, and soil physical and chemical properties, as well as the metals concentrations and forms. Very high rates of biosolids application were necessary to observe a high uptake of metal by plants, usually >100 mt/ha. With lower rates there was no additional uptake of metals by plants (Harrison et al., 1990).

This brief summary of findings of ecological impacts of the treatment/disposal of biosolids suggests that these issues should be considered in the development of a decision-making model for the treatment/disposal of treated municipal biosolids.

Political/institutional considerations

If a community wanted to implement an operational-scale project, such as the Ames Agroforestry Project, there are people who could hinder its success. The EPA (1983) process design manual for land application of biosolids suggests that: "Project implementation requires acceptance and approval by local officials, farmers, landowners, and other affected parties." Hadwiger (personal communication, 1992) pointed out that, in general, most communities have a structure of decision-makers that have authority over the implementation of innovation. A simple diagram of this structure is depicted in Figure 4.

At the top layer of the decision-making diagram are the voters. In most cases it is unlikely that the general public, in large numbers, would be involved actively in decisions about operational concerns at the WPCF. There are situations, however, that could stimulate concern and result in considerable public involvement.

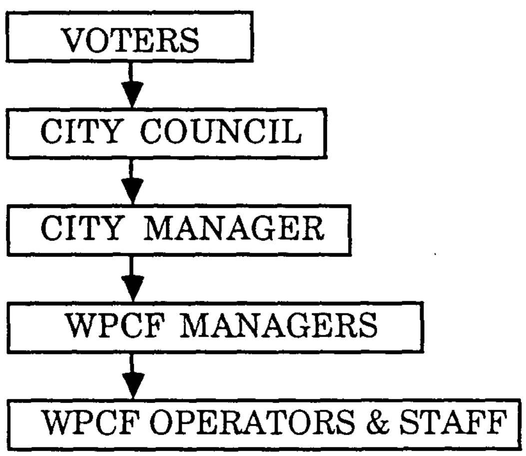

Figure 4. Hierarchy of authority for decisions regarding activities associated with a municipal water pollution control facility (WPCF)

In many cases, issues relate to community health risks, environmental pollution, or threats to personal property values or ownership. Usually this does not occur for operational concerns such as those surrounding municipal biosolids treatment/disposal. Most problems at a WPCF are handled by individuals at the lower end of this political structure.

This is not to suggest that public involvement is not a part of the decision-making process. In fact, public involvement is critical to the overall success of a biosolids treatment/disposal program (USEPA, 1983). For example, public hearings are required during the siting and construction of WPCFs. People in attendance would usually be adjacent land owners or people to be affected downstream, as was the case for the Ames WPCF hearing in 1989. If the voting public became highly involved, this ultimately could affect the decisions made by the city council or city manager concerning the operation of the WPCF.

The city council is the next level of influence in Figure 4, and it would have more direct concern over the development of an innovative idea. City councils like to be recognized for innovation, especially those that will bring recognition to their community. One example is the All-American City award. Essentially, recognition for successful innovation, without negative press, would be a goal for the city council (Hadwiger, 1992).

Another concern of the city council is to minimize the conflict in the community. In relation to biosolids treatment/disposal, four general labels for these factors are: nuisance, health, public safety/environmental protection, and budget (Hadwiger, 1992). The city council has overall responsibility for these issues, but specific responsibilities for programs fall on the shoulders of the city manager and the managers of the municipal facilities. Hadwiger (1992) pointed out that the city council typically has the goal of re-election in mind. To that end, the above-mentioned concerns have specific ramifications. In general, many of the concerns could be seen as avoidance issues, tied very closely to fear of possible litigation. The city council would be concerned with potential lawsuits occurring in response to nuisance, health, and public safety issues from WPCF operations. Actually, however, avoidance of litigation would be the responsibility primarily of the WPCF managers, not the city council.

Finally, according to Hadwiger (1992), cost efficiency is the most important budget concern of the council. Thus, the council wants to make the most cost-effective decision possible, regarding the land application of biosolids.

The next level of community government involved with biosolids treatment/disposal is the city manager (Hadwiger, 1992). The important characteristics of the city manager, different from the city council, are those related to personality and concerns for professional advancement. Katz and Kahn (1978) discussed role theory, suggesting that role definitions for a city manager are developed largely from one's own personality as well as from the expectations of others rather than the job of city manager. The potential for innovation is highly dependent on the personality of the manager. Whether the manager is a risk-taker or a risk-avoider will determine whether or not some new idea will be attempted. Nalbandian (1991) suggested that managers are administrative leaders who take special pride in seeing the results of their work.

Beyond the above mentioned factor, the concerns of the city manager are probably similar to those of the city council, although the concerns will be more personalized because of career concerns (Hadwiger, 1991).

As would be expected, the WPCF managers and staff are the bottom level of the authority diagram for community actions. Being the most closely involved with operational decisions, this agency likely would be the initiator of an innovation, if it is within their area of responsibility. The staffing organization of the WPCF will vary depending on the size of the plant and the community. Figure 5 shows the organizational chart of the City of Ames WPCF.

Ultimately, the plant superintendent is responsible to the city manager and to the city council for the actions of the WPCF. This part of city government provides the technical expertise and links the local community and other state and federal governments. Figure 6 depicts the role that the WPCF mangers play.

The WPCF managers need to be aware of the interests of their community including the city government (city council, city manager), and of all regulations involved with municipal waste management and regulation changes.

The position at the center of Figure 6 may suggest that the WPCF managers are placed in a defensive role. Ringelestein (1992), however, pointed out that Ames' WPCF relationship with city government and the IDNR is cooperative rather than defensive.

Problems with political/institutional relations do arise, and communities have become embroiled in controversy because of their waste treatment/disposal methods. The city of Des Moines, Iowa became involved in a controversy over its land application program in 1975 when a group of citizens raised the issue of the city's handling of municipal biosolids. The controversy resulted in a state regulation being passed that banned land application of biosolids in Iowa. The regulation was remanded because of the

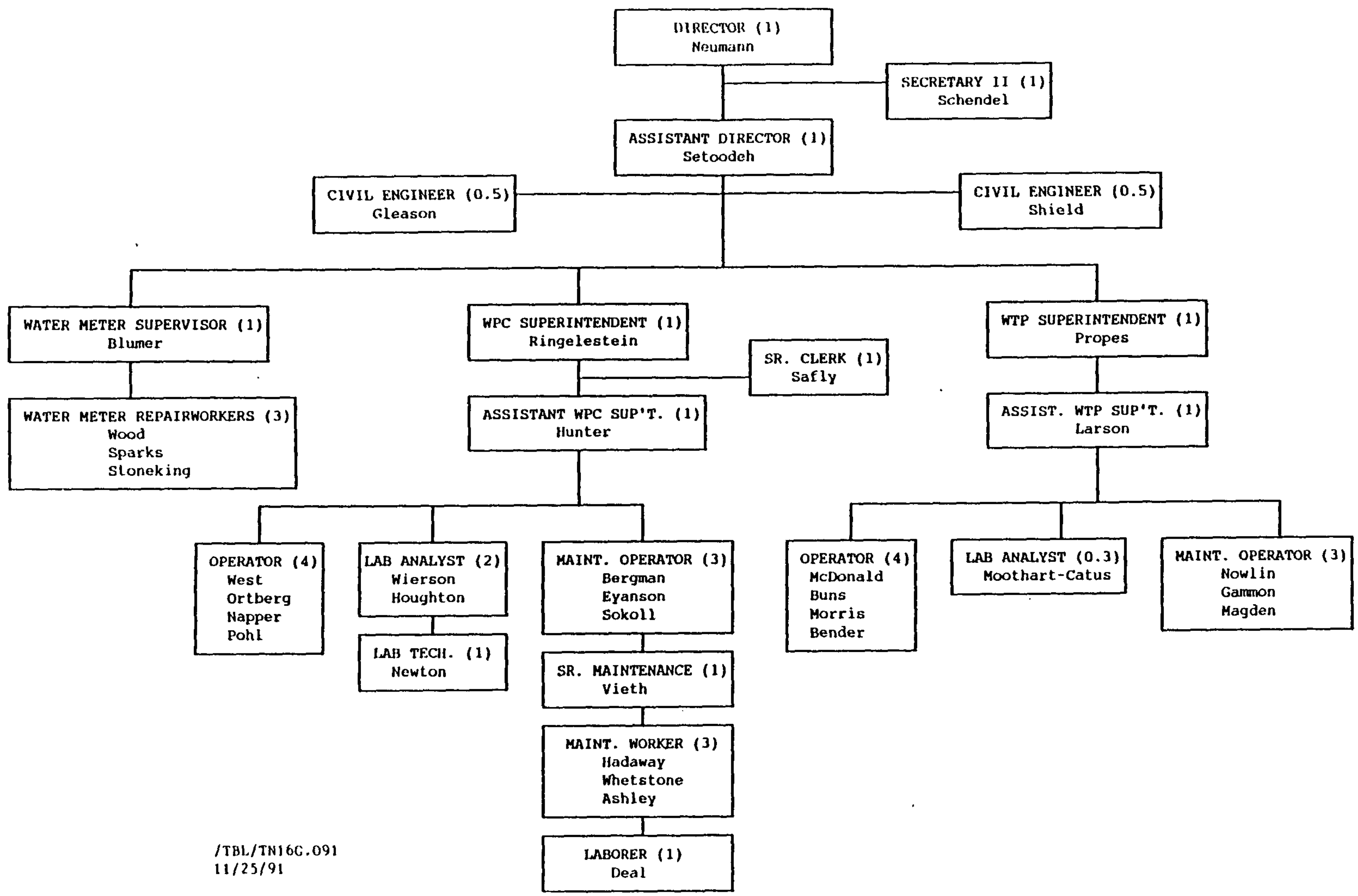

Figure 5. Organizational chart of the Ames WPCF (Source: City of Ames, WPCF)

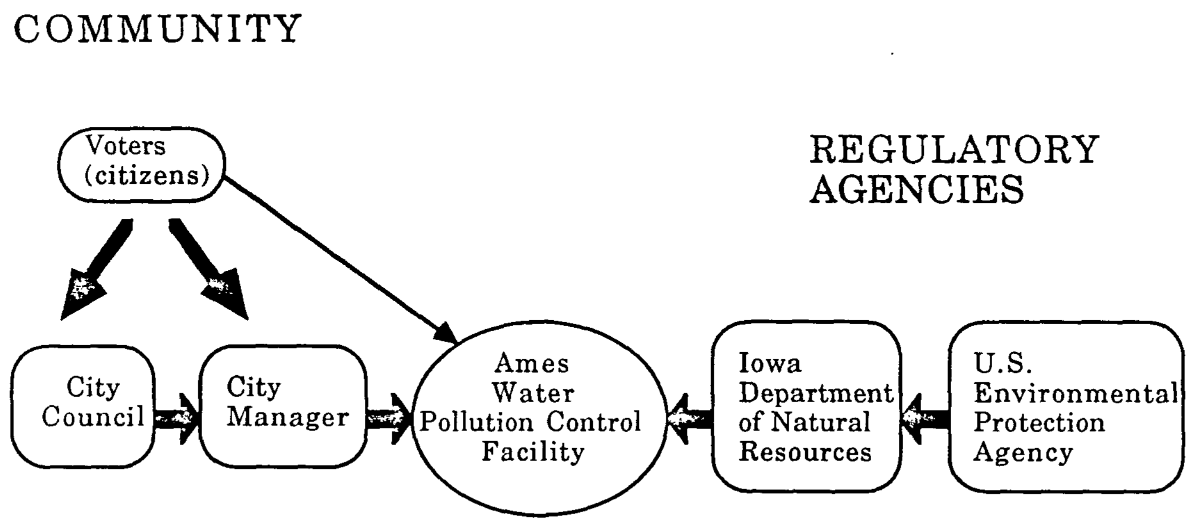

Figure 6. Role of WPCF managers in relation to public, and city, state, and federal governments

infeasibility of the law. However, Des Moines' position for biosolids utilization has been a precarious one ever since, and has resulted in limited opportunity for land application of biosolids on agricultural land near residential areas (Ringelestein, 1992).

Additionally, the WPCF manager must maintain a good working relationship with the other arms of city government. This means that the concerns of the city council and the city manager are significant to the success of their WPCF operation. By not giving due consideration to biosolids issues that arise in relation to city business, a WPCF manager could risk serious difficulties.

Other constraints, which effect WPCF managers' decision-making, are related to questions of technological feasibility and whether the technology is affordable. As with the city manager and the city council, the WPCF manager has a budget that limits implementation of innovation and requires careful decision-making.

There are two general types of agencies in government (Hadwiger, 1992). The first is the "play-it-safe" agency that can briefly be characterized as having an attitude of trying to get the job done with the least amount of effort, and conflict. This kind of agency is risk-avoiding. These characteristics tend to result in the agency staying the same size, even during times of growth in a community, or getting smaller because of a lack of motivation. The second type of agency is the innovative type. This type of agency is concerned with developing and implementing new ideas and with being progressive, especially concerning technological advancement. Two motivating factors for an innovative agency is money, and the hopes of expanding responsibilities (Hadwiger, 1992). Given these types of agencies, the Ames WPCF would be categorized as innovative, if for no other reason than simply because it initiated the Ames Agroforestry Project.

In general, the feasibility of a new venture will be determined through a complex process of decisions. Two general perspectives relative to a new venture can be taken. First, how does the new idea fit into the existing political picture? The other perspective is to view the innovation looking from the administrative structure. Are the decision-makers (i.e., city council, city manager, WPCF managers) innovative and malleable enough to work change into their realm of responsibilities?

Regulation Nationwide, land application as a municipal waste treatment/disposal method has been federally accepted since the passing of the Water Pollution Control Act Amendments of 1972 (PL 92-500). Reaffirmation of this treatment/disposal method came from the passing of the Clean Water Act of 1977. This act provided further financial incentives beyond those provided in PL 92-500 to develop innovative and alternative approaches to human and industrial waste management.

Water pollution regulation in the U.S. has constantly changed over time. Following the actions and regulations over the past 20 years is difficult a task. However, the passage of the Federal Water Pollution Control Act Amendments of 1972 (FWPCA) marked a turning point in the approach taken toward the problem of water pollution control in the U.S. (Moss, 1977). Section 208 of the Act focused on ensuring a goal of "water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water." This goal was to be achieved by 1983. Section 201 of the Act authorized the EPA Administrator to make grants for the planning and construction of publicly-owned sewerage treatment plants (Moss, 1977).

The specific regulations regarding contaminants, heavy metals, etc., and standards for WPCF's treatment/disposal of biosolids are still based upon the 1972 standards. New EPA standards are pending. In February of 1989, the new Part 503 recommendations had been written. These regulations were regarded by Dr. Alan Rubin, Chief of the Sludge Regulatory and Management Branch in EPA's office of Water Regulations and Standards, "as the first comprehensive rule for sludge for technical regulations" and a multi-media waste management rule (Goldstein 1989). The regulations, however, are still under review and their release date is still uncertain.

According to Ringelestein (1992), the Ames WPCF is most closely regulated by the State of Iowa which enforces federal guidelines promulgated and enforced by the EPA. The current stipulations of the Ames WPCF permit deal with specific limitations of heavy metals (such as lead, zinc, and cadmium), nitrogen, and other potential contaminants.

Social considerations

Social concerns over environmental issues vary greatly. Social impact assessment (SIA) is a methodology developed to evaluate social concerns arising from change. A vast subject, an SIA is beyond the scope of this study. Figure 7 outlines Social Impact Assessment.

Social issues can have considerable impact on projects such as the Ames Agroforestry Project (AAP). Thus, it is critical that social concerns be addressed in a systematic, comprehensive analysis, although in this case not an SIA.

Finsterbusch (1981) identifies SIA as a tool to facilitate the decision-making process by "determining the full range of costs and benefits of alternative proposed courses of action".

Figure 7 shows a very simplified flow chart of questions to be addressed during the SIA process. The diagram is included to illustrate the process, but because of a limitation of time and space the assessment steps will not be discussed in detail.

Bultena (personal communication, 1992) identified two disparate sets of issues that arise when considering a project such as the AAP. One group of

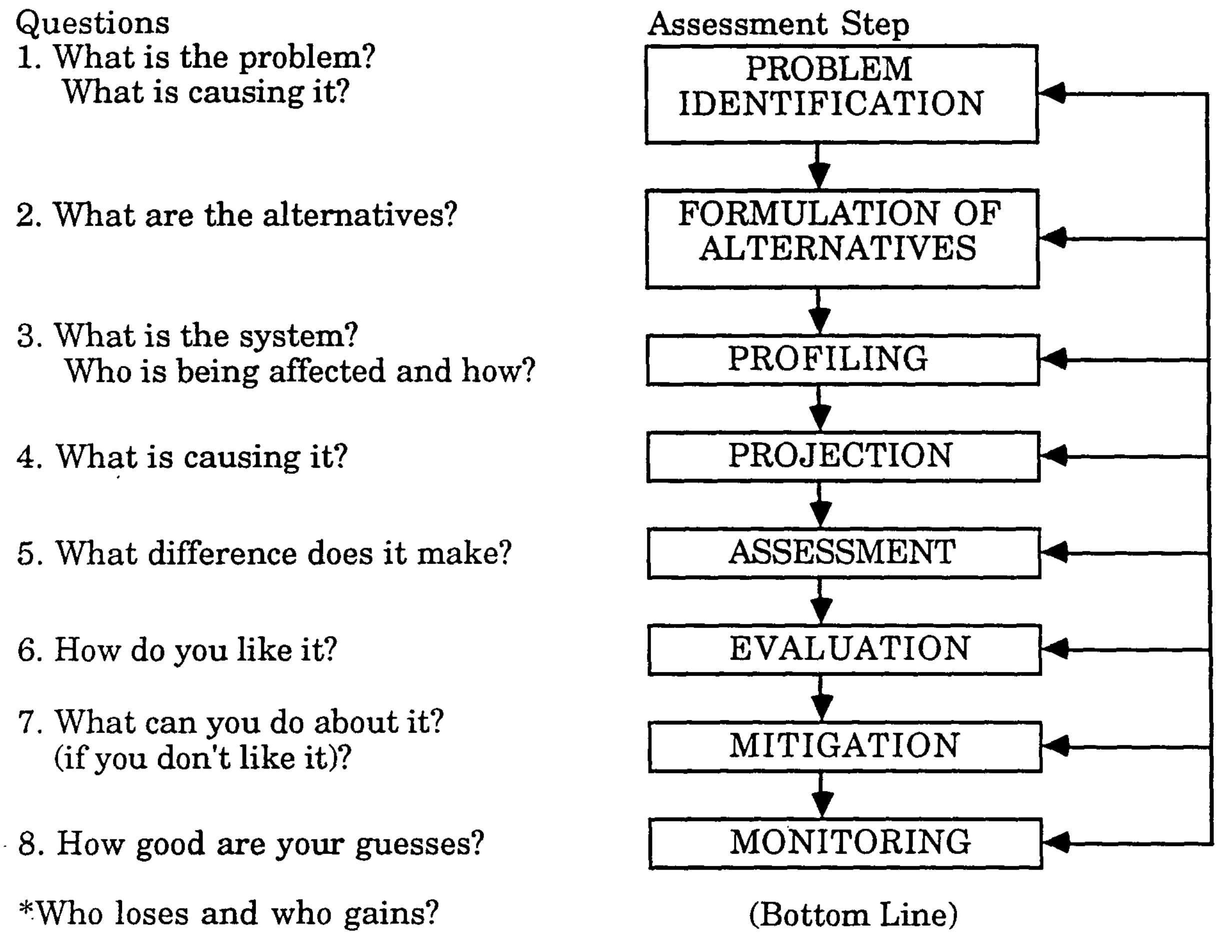

Figure 7. Social impact assessment: The Main Pattern from Wolf, 1981

social issues would arise from acceptance of change by individuals who ultimately might be affected by the change. The second set of issues are associated with actual physical site-specific impacts.

For the AAP the two groups are farmers in the state and local area, and people who would be directly affected by the treatment/disposal of biosolids. Both groups are involved with both sets of issues.

Bultena (1992) suggested that farmers would be an important group to consider in the development of AAB systems as an alternative for the treatment/disposal of biosolids. Farmers acceptance of AAB systems as an alternative cash cropping system will determine whether a market system will be established for the products produced from the system. Acceptance of innovation is very much tied to people's willingness to change and little on whether or not it has a great advantage over the idea it is replacing. Further, adoption will be influenced significantly by the innovation's compatibility with existing values and past experiences of the adopters (Rogers, 1962).

Rogers (1962) also suggested that the innovation's characteristics will affect whether it is adopted, or the rate at which it is adopted. Complexity of the innovation will affect the rate of adoption. Thus, increased complexity can eliminate the new idea being used, or increase the time it takes for adoption. Divisibility is the degree that an innovation can be tried on a limited basis. If a new idea can be used on a "trial basis" it will have a better chance of being used. Communicability, on the other hand, is the degree to which an innovation can be observed and communicated to other potential users of the innovation. Thus, the setting, or the history of an area will have an impact on social issues.

Bultena (1992) suggested that deforestation in Iowa would provide some impetus for acceptance of AAB systems by citizens of the state. Because Iowa has been converted primarily into an agricultural state for the production of corn and soybeans, biological diversity has been reduced substantially. Visual diversity likewise has been reduced. A likely expectation would be that more biological diversity would be desirable, especially if it offers economic returns in the form of increased products and tourism.

However, determining these returns could be a difficult task. For example, in the past few years, travel and tourism for Iowa has become very important. It would be nearly impossible to quantify the increased income from more tourists because of increased biological diversity - or to even determine whether the increase in tourism was a result of more biological diversity.

Bultena (1992) suggested that the citizens of Iowa probably would accept a nominal increase in biological diversity, so there is reason to initiate new technologies such as AAB systems. This would be especially true if AAB systems can offer similar economic returns as current agricultural practices.

Somewhat easier to identify are site-specific issues. Problems arising from complaints of adjacent landowners or citizens being directly affected by operations are simpler for WPCFs to identify. These issues would stem from both consumptive and non-consumptive uses of impacted resources (e.g., with water these two uses would be potable water, and water for recreational use) by adjacent landowners, and by people living downstream from the WPCF. An important point for these concerns is that they can be "real" or "imagined" risks. In fact, imagined risks often can be greater blocks to change than are "real" concerns (Bultena, 1992).

Concerns of these people would be for human health risks and nuisance problems associated with land application of municipal biosolids. Health risks are tied to the "pernicious contraries" part of biosolids. Specifically, these are human health risks from the ingestion of or contact with heavy metals, nitrogen, or other chemicals which might get into drinking or recreational water, or the human food chain. Federal regulations of municipal biosolids are oriented towards managing these concerns, although it is unclear whether they adequately control these problems.

Contamination of groundwater by nitrates and other chemicals is a real concern for Iowa. Because biosolids are high in nitrogen content, concerns for controlling leaching into the ground and surface waters are notable.

Nuisance, or "not-in-my-back-yard" (NIMBY) issues are another site-specific concern that arise from land application of municipal biosolids. Odor would be the most distinctive attribute usually associated with biosolids. There usually is not a strong odor associated with treated biosolids. This is because through the biological treatment process (oxidation) the organics found in municipal sewage are digested into organics. In any case, the concern, whether real or not, is there. A second possible nuisance issue would be visual. Above-ground application of biosolids leaves a black coating on the ground and on vegetation. This impact will be quite apparent until the material dries, or until a rainfall occurs.

An additional group of concerns for adjacent landowners could arise in relation to impacts on their property. A drop in real property value or an impact on a herd of animals can bring about controversy.

The AAB system can provide benefits that do not fall necessarily within the categories specified. As suggested by Bultena (1992), pressures toward sustainable agriculture, and increasing prices for fuel are pushing the agricultural community toward more diversity in production. In the future, AAB applications offer a greater diversity of plants, and this in turn offers potential social benefits. For example, AAB systems with a more diverse landscape would result in more, or better, wildlife habitat. This diversity would enhance both appreciative and consumptive types of opportunities for people.

In the light of sustainable agriculture opportunities, biosolids is an alternative to the use of petroleum-based commercial fertilizers which typically require non-renewable energy to produce. Additionally, biosolids work better because they provide a "more natural" type of fertilizer. And, as the real price of oil increases, so too will the price of these fertilizers.

The development of a decision-making EIA type model to consider impacts seems overwhelming, especially given the vast number of concerns that can be associated with change. It might seem impossible to consider all possible impacts adequately. A series of well-thought-out questions, however, can give proper consideration to most concerns. With consideration comes a better understanding of the situation which, ultimately, will result in a better decision.

CHAPTER III. OBJECTIVES

Alleycropping agroforestry for biomass (AAB) seems to offer an alternative method for the land treatment/disposal of municipal biosolids. There are, however, several ecological, political, and social issues that must be addressed . Additionally, the alternatives must be compared economically by municipalities. Federal and state governments have attempted to develop guidelines for these decisions, but site-specific concerns can vary greatly. Specifically, the objectives for this research are:

1) To develop an Environmental Impact Assessment (EIA) decision-making model for the land application of municipal biosolids for use as a renewable energy resource giving consideration to economic, ecological, political/institutional, and social factors.
2) To apply the model to the Ames Agroforestry Project to determine its feasibility.

CHAPTER IV. METHODOLOGY

This research involved 1) identifying a series of criteria and "impact" questions by assessing impacts associated with economic, ecological, political/institutional, and social issues resulting from the land application of municipal biosolids, 2) quantifying the costs and revenues associated with the AAB and status quo alternatives, 3) performing an economic analysis based on costs and incomes of the alleycropping agroforestry for biomass (AAB) system and the status quo alternatives, and placing relative values for "impact" questions into a decision matrix, and 4) evaluating the alternatives based on their economic performance and attainment of "impact" questions.

Identification of criteria and "impact" questions

The first step of this analysis process was to decide on the criteria by which the alternatives for biosolids treatment/disposal would be evaluated. The approach used was to identify a series of questions that address the major issues raised when considering the potential impacts from the land application of treated municipal biosolids, and to develop criteria to measure the attainment of these issues. The criteria and questions will be presented for each area of consideration as discussed previously.

The questions and criteria are placed on the vertical axis of a matrix with the alternatives across the horizontal axis (see Table 1). Three alternatives were used. The status quo alternative is the current situation at the Ames WPCF, which is a rotation of corn and soybeans with biosolids applied annually at a rate of 168 kg/ha (1X). The second alternative is the AAB

1X alternative which stands for an AAB system with 168 kg/ha (1X) of biosolids being applied annually. The third alternative is the AAB 2X (336 kg/ha of biosolids being applied).(see Table 1). A detailed description of the alternatives presented in the economic analysis section.

Following is a listing of the questions and criteria under each area of consideration for this analysis.

Economic

1) Are the identifiable market benefits greater than the costs for the AAB system?
2) How cost effective are the three alternatives?

For this area, two common economic measures have been chosen to evaluate the economic performance of the alternatives: Present Net Worth (PNW) and Annual Equivalent Worth (AEW).

Ecological

1) Are environmental risks associated with heavy metals or other contaminants minimized for plants, animals, and water resources?
2) Is potential for nitrogen contamination of ground and surface water minimized?
3) Is wildlife habitat enhanced?

Political/institutional considerations

1) Does the new idea fit into the "new" environmental concerns of the public? Is the idea "in vogue?"

2) Has the idea been tried and proven, and is there a similar endeavor underway in proximity to the proposed project?
3) Will the project improve relations between arms of government?
4) Does it fit within the current routines of the existing institutional structure?

Social considerations

1) Are health risks associated with contamination of food or water minimized?
2) Are aesthetics enhanced?
3) Is the potential for nuisance issues minimized (NIMBY)?

Many other questions could be identified under each of these areas. However, these questions adequately address the major concerns regarding the land application of municipal biosolids.

The decision matrix

The economic criteria will use actual costs of establishment and maintenance from the three different alternatives. Revenues are calculated based on expected yields and prices for energy and crops. The economic criteria are the only items that have been quantified in the matrix (see Table 1).

Several methods of evaluation could be used for the questions identified for ecological, political/institutional, and social areas of consideration. A commonly used method is to develop a scale of response,

Table 1. Blank matrix of economic values, and qualitative values for attainment of questions in ecological, political/institutional, and social areas of consideration

	ALTERNATIVES		
CRITERIA	Status Quo	AAB 1X	AAB 2X
Economic			
PNW			
AEW			
Ecological			
Minimization of heavy metals impact			
Minimization of nitrogen impact			
Wildlife enhancement			
Political/Institutional			
"in vogue" environmentally			
Tried & proven-similar projects nearby			
Improve relations between arms of government			
Workable within institution			
Social			
Health risks minimized			
Aesthetics improved			
NIMBY issues minimized			

such as a scale from one to ten. However, determining reliable scales associated with ecological, political/institutional, and social concerns is beyond the scope of this analysis. What will be used is a relative scaling of low, medium, and high. This relative scaling is intended to give a qualitative measure of the achievement of the ecological, political/institutional, and social questions within these areas of consideration.

Economic Analysis

The Ames Agroforestry Project (AAP) has three crops that are being produced, 1) hybrid poplar, 2) switchgrass, and 3) sweet sorghum. All three crops are to be used as biomass for energy production. Currently, the Ames WPCF applies biosolids to farmland owned by the city which is rented to a private farmer who produces corn and soybeans in a rotation of crops - status quo alternative. This analysis is designed to compare these two cropping systems based on Present Net Worth (PNW) and Annual Equivalent Worth (AEW) criteria. These combinations of cropping systems are referred to as alternatives. Thus, the three alternatives being analyzed are the status quo, and two AAB systems that vary because of biosolids application rates. Because each alternative is a combination of crops, it was necessary to calculate specific costs and revenues for different crops, called scenarios. All cost items will be expressed in constant dollars and presented on a per hectare basis for five different scenarios. For specific cost data, refer to Tables 2 to 6.

The analysis period for all scenarios and the three alternatives, is twenty one years, which was chosen because it represented a common multiple of the project lives for all crops. This analysis period allows for three seven-year rotations of SRWC crops and twenty-one annual harvests of switchgrass and sweet sorghum. Harvests for the status quo scenarios occur every other year for twenty-one years. For specific timing of activities refer to Appendix A, the QUICK-SILVER analysis.

Status quo alternative

The status quo alternative is a combination of corn and soybeans in annual rotation. Thus, it was necessary to develop costs and revenues for two scenarios for this alternative: corn following soybeans, and soybeans following corn. Currently, the corn and soybeans are being produced for cereal grains; thus, incomes for both scenarios are based on the current (1992) cereal grain prices multiplied by the expected yields. Because the status quo alternative has biosolids applied at a rate of 1X (approximately 168 kg/ha) (no other biosolids application rates can occur because of current federal regulations), this alternative does not vary for biosolids application rates.

Corn following soybeans/soybeans following corn Specific cost data for these two scenarios are listed in Tables 2 and 3. Except for the application of municipal biosolids, these scenarios involve conventional production of corn and soybeans on a yearly rotation. The costs for these two scenarios are based on the Iowa State University (ISU) Extension publication Fm-1712/November 1991 entitled "Estimated Costs of Crop Production in Iowa - 1992" (Duffy and Judd, 1992). The variation in scenario costs from the publication are associated with the utilization of biosolids as a fertilizer rather than using commercial petroleum-based fertilizer. Because the biosolids do not provide all necessary nutrients for optimal corn production, additional commercial

Table 2. Cost data used for the corn following soybeans scenario in the status quo alternative

Cost item[b]		309 bushels per hectare Fixed	Variable
Preharvest Machinery		$39.96	$17.37
Seed, Chemical, etc.			
Seed @ $0.89/1000	56,833		$50.58
Nitrogen @ $0.31/kg[a]	20.17		6.25
Phosphate @$0.51/kg	51.55		26.29
Potash@ $0.29/kg	67.24		19.50
Lime			14.83
Herbicide			48.43
Crop Insurance			13.59
Miscellaneous			22.24
Interest on preharvest variable costs (8 mo. @ 12%)			19.27
Total			$220.98
Biosolids Application Vehicle			$204.52
Harvest Machinery			
Combine		$40.50	$22.81
Haul		5.88	5.56
Dry		12.36	23.15
Handle		4.20	1.85
Total		$62.94	$53.37
Labor			
7.4 hours @ $6.00/hr		$44.40	--
Land			
Cash rent		$247.10	--
Total fixed, variable		$541.70	$496.24
Per hectare			
Per bushel		$1.75	$1.61
Total cost per hectare		$1037.94	
Total cost per bushel		$3.36	

[a] Fertilizer rates based on actual rates applied by farmer operator using Ames WPCF lands.
[b]Based on data from Duffy and Judd (1991), Estimated costs of crop production in Iowa - 1992.

Table 3. Cost data used for the soybeans following corn scenario in the status quo alternative

Cost item[a]		94 bushels per hectare Fixed	Variable
Preharvest Machinery		$38.33	$16.56
Seed Chemical			
Seed @ $14.00 per bushel	2.471		$34.59
Phosphate @$0.51/kg[b]	33.62		17.15
Potash@ $0.29/kg	67.24		19.50
Lime			14.83
Herbicide			45.96
Crop Insurance			18.53
Miscellaneous			22.24
Interest on preharvest variable costs (8 mo. @ 12%)			14.50
Total			$187.30
Biosolids Application Vehicle			$204.52
Harvest Machinery			
Combine		$34.74	$17.25
Haul		1.78	1.68
Handle		1.36	.62
Total		$37.88	$19.55
Labor			
6.4 hours @ $6.00/hr		$38.56	--
Land			
Cash rent		$247.10	–
Total fixed, variable			
Per hectare		$361.87	$427.93
Per bushel		$3.85	$4.55
Total cost per hectare		$789.80	
Total cost per bushel		$8.40	

[a] Fertilizer rates based on actual rates applied by farmer operator using Ames WPCF lands.
[b]Based on data from Duffy and Judd (1991), Estimated costs of crop production in Iowa - 1992.

fertilizer was used. Fertilization rates are based on the actual rates applied by the farmer-operator who grows corn on Ames WPCF land. The use of biosolids substantially reduced the costs for nitrogen fertilizer. However, additional amounts of fertilizer were applied in the amounts of 20 kg of nitrogen, 52 kg of phosphorous, and 67 kg of potassium per hectare (Ringelestein, 1992). An additional cost item is included for the biosolids application vehicle ($204.52/ha). This cost item was used for all scenarios for comparability.

Income for the corn following soybeans scenario is based on expected yields of 309 bushels/hectare (Ringelestein, 1992). Price per bushel is based on average price for corn of $2.36 for 1988-1990, as specified by the document entitled "1990 Iowa Agricultural Statistics" produced by the Iowa Department of Agriculture and Land Stewardship (IDALS) (Skow and Holden, 1990).

Income for the soybeans following corn scenario is based on expected yields of 94 bushels/hectare (Ringelestein, 1992). Price per bushel is based on average price for soybeans of $5.50/bushel for 1988-1990 (Skow and Holden, 1990). A spot pricing from the Des Moines Register, 21 June 1992, listed the price of corn at ~$2.35/bushel and beans at ~$5.76/bushel.

<u>Alleycropping agroforestry for biomass (AAB) alternatives</u>

Because the AAB system is comprised of three cropping systems, the alternatives are subdivided into three scenarios as modeled after the AAP. The first scenario in the AAB alternative is the short-rotation woody crop (SRWC) scenario - a plantation of populus as found in the AAP. The second scenario is the switchgrass cropping system. The third scenario is the sweet sorghum cropping system. For each of these scenarios, a cost stream (negative cash flows) was identified for the different management activities necessary for producing these crops. All incomes for these scenarios were based on expected yields from the crops, multiplied by the expected market price of biomass for energy.

Variation between scenarios occurs based on the biosolids application rates that are currently being used for the AAP. Thus, for each scenario, biosolids application rates of no biosolids (0X), 1X, and 2X were calculated. Inasmuch as the 0X biosolids application is included as an "experimental control," this scenario was not included as an alternative in the comprehensive analysis. Specific cost for biosolids application cost is based solely on operating cost for the biosolids application vehicle at $204.52/ha (1X biosolids application) (Ringelestein, 1992).

<u>SRWC scenario costs</u> The cost data for the SRWC scenario of the AAB alternative are based on a combination of cost data derived from a number of sources described in the following sections. All costs were figured on a one-hectare basis for a plantation of hybrid poplar trees (*Populus x euramericana* - clone NC-5326) and are in constant 1992 dollars. For a specific listing of costs for these scenarios refer to Table 4 and to the QUICK-SILVER analysis in Appendix A.

<u>Site preparation costs</u> The AAP site was previously farmed. Thus, site preparation for the SRWC scenario involved typical farming operations. One chisel plowing and one discing were sufficient to prepare the site for planting. Costs for these activities were derived from Judd and

Table 4. Cost data used for the SRWC scenarios in the alleycropping agroforestry for biomass (AAB) alternatives

Activity	Cost	Aggregate Cost
Site Preparation		
chisel plow	$22.75/ha	
discing	$17.05/ha	
Planting		
planting stock[a]	$734.14/ha	$835.50/ha
tractor	$19.77/ha	
planter	$2.55/ha	
labor	$79.07/ha	
Cultural Management		
Weed control:		
herbicide and application	$92.60/ha	$109.90/ha
mowing	$17.30/ha	
Fertilization[b] (biosolids application vehicle)	$204.52/ha	$204.52/ha
Land Rent	$247.10/ha/yr	$247.10/ha/yr
Harvesting[c]	$256.88/ha	$256.88/ha

[a]3,337 seedlings/ha x $0.22/seedling.
[b]Based on biosolids application vehicle operating costs @ $82.77/hr. No cost is charged for biosolids.
[c]$26.00/dry-metric ton, including $2.00 for transportation x 9.88 dry metric tons/ha (assumed woody biomass yield).

Edwards (1992). Custom rate for chisel plowing is $22.75/hectare, and discing is priced at $17.05/hectare.

Planting costs Costs for seedlings in this analysis are based on prices from the IDNR state forest nursery in Ames, Iowa (@ $22.00 per 100 for 1992). At the AAP site, the SRWC portion of the planting occupies one-half of the total area. With spacing of 2.4 m between tree rows and 1.2 m between trees and 4.6 m for the biosolids application alleys (see Figure 2), 3,337 seedlings are needed to plant one hectare.

Based on the planting at the Amana Society project in 1992, four laborers, a small 50-horse power (hp) tractor, and a one-row tree planter were required to plant one hectare in approximately 4.3 hours. The Amana planting was for research purposes so it is expected that planting costs for farmers would be lower. A source from the IDNR suggested it would take only 2.47 hours to plant one hectare. For this analysis, an average planting time between these two values was used, approximately 3.2 hours per hectare.

Tractor costs were derived from Judd and Edwards (1992). Based on their procedure for estimating tractor cost for a 50-hp tractor, tractor rental cost for planting would be approximately $20/hectare.

Hourly cost for the planter for one hectare was determined by using the planter purchase price, equipment life, and expected yearly usage. Purchase price is $5,000 and a fifteen-year life with a maximum usage of 720 hours per year (90 days x 8 hrs per day) were assumed. The purchase price was multiplied by the 15-year discounting factor for an 8% discount rate (0.11683) to determine the discounted average yearly cost of the planter. That value was then divided by the yearly hourly usage (720), to give an hourly cost of $.80 (see calculation below). The hourly cost was then multiplied by the average planting time per hectare.

$5000 (planter purchase price)
0.11683 (15 year discounting factor @ 8% discount rate)
720 (hours of use per year)

$$5000 \times 0.11683 = \frac{\underline{594.15}}{720} = @\ \$0.80/\text{hr} \times 3.2\ \text{hr/ha} = @\$2.55/\text{ha}$$

Planting labor was based on four laborers planting one hectare in approximately 3.2 hours. At a labor cost of $6.20/hr x 4 laborers for 3.2 hours per hectare, planting labor would be approximately $79 per hectare.

Cultural Management Weed control at the AAP has involved a combination of herbicide application and mowing. For the first 2 years of the project, mowing was the only form of weed control. Two mowings per year proved to be marginally effective on controlling the weed population. Because of the limited effectiveness of mowing, and because of expensive equipment rental rates and labor cost, it was decided that herbicide would be applied as an additional measure to control weeds. For this analysis, custom herbicide application and mowing costs from Judd and Edwards (1992) were used.

Herbicide application would occur in the fall of the first two years of plantation establishment and two years following plantation harvesting. Surflan would be used at a rate of 2.24 kg/ha and Roundup (glyphosate) at a .5% aqueous solution (a.s.). Per hectare costs for these chemicals are $79.00/ha and $1.25/ha, respectively. Custom application costs are $12.36/ha, giving a total cost of $92.60/ha for herbicide weed control.

Mowing cost was based on Judd and Edwards' (1992) custom rate of mowing for CRP or diverted acres at $17.30/ha. Mowing would occur also for the first two years of plantation establishment and for two years following each harvest.

Total cultural management costs are $109.90/ha.

Fertilization For the SRWC scenario, the only fertilization to occur is from the application of biosolids. Thus, for the analysis, the biosolids application vehicle cost varies depending on the application rate 0X (no cost), 1X (one application, at $204.52/ha), and 2X (two applications at $204.52/ha). This activity is the only variable cost for the three SRWC scenarios.

Land cost Land cost was determined from the actual rental rate charged by the city of Ames to rent property to a farmer operator. Currently, land rent is $247.10 per hectare. This cost is used for all scenarios and all alternatives.

Harvesting cost Cost for harvesting is based on U.S. Department of Energy (DOE) estimated costs for harvesting, handling, and delivery of biomass for energy (Wright et al., 1989; Campbell, 1988). A cost of $26.00/dry metric ton, including $2.00 for transportation, was used for this analysis. This value was multiplied by the expected yield of 9.88 dry metric tons/ha, giving a total harvest/transportation cost of $256.88/ha.

Income for this scenario is based on estimated yields of 9.88 dry metric tons of biomass/hectare/year (Colletti et al., 1991). Price per metric ton is based on DOE-estimated price for biomass for energy at $40.00/dry metric ton (Wright et al., 1989). No increase of biomass production was included for increasing biosolids application from 1X to 2X, based on Johnson et al. (1987) where an increased use of biosolids, beyond 168 kg/hectare showed no increase in biomass production.

Sweet sorghum scenario Because sweet sorghum and corn are similar crops, costs for this scenario are considered similarly. Specific activities are based on actual practices used for growing sweet sorghum by the ISU Department of Agronomy (Accola, 1992) and using ISU Extension publication Fm-1712 (Duffy and Judd, 1991). There are some differences for handling and harvesting, and those costs were based on custom rates from ISU Extension publication Fm-1698 (Judd and Edwards, 1992). As with all other scenarios, there is an additional cost item included for the biosolids application vehicle. For specific costs for this scenario, refer to Table 5.

Table 5. Cost data used for the continuous sweet sorghum scenarios in the AAB alternatives

Cost item[b]		Assumed yield 17.6 dmt/hectare[a] Fixed	Variable
Preharvest Machinery		$40.30	$17.25
Seed, Chemical, etc.			
Seed @ $0.20 per 1000	176,013		$35.20
Nitrogen @ $0.31/kg[c]	20.17		6.25
Phosphate @$0.51/kg	51.55		26.29
Potash@ $0.29/kg	67.24		19.50
Lime			14.83
Herbicide			48.43
Crop Insurance			13.59
Miscellaneous			22.24
Interest on preharvest variable costs (8 mo. @ 12%)			19.27
Total			$205.60

[a] Based on research results of average yield of 17.6 dry metric ton/ha (dmt) when applying 140 kg of N/ha. Data from Agronomy & Agricultural Engineering Research Center ISU, - Ames. (Anderson et al., 1991).

[b]Based on data from Duffy and Judd (1991), Estimated costs of crop production in Iowa - 1992.

[c] Fertilizer rates based on actual rates applied by farmer-operator using Ames WPCF lands.

Table 5 Cont.

Biosolids Application Vehicle			$204.52
Harvest Machinery			
Forage chopper		$21.25	$17.42
Haul		7.04	5.63
Dry		11.37	21.30
Handle		3.83	1.61
Total		$43.49	$46.96
Labor			
8.4 hours @	$6.00/hr	$50.40	--
Land			
Cash rent		$247.10	--
Total fixed, variable			
Per hectare		$381.29	$474.33
Per metric ton		$21.66	$26.95
Total cost per hectare		$855.62	
Total cost metric ton		$48.63	

Income for this scenario is based on estimated yields of 17.6 dry metric tons of biomass/hectare/year (Anderson, et al., 1991). Price per metric ton is based on DOE-estimated price for biomass for energy at $40.00/dry metric ton (Wright et al., 1989). No increase of biomass production was included for increasing biosolids application from 1X to 2X, based on Anderson et al. (1991), where an increased application of fertilizer showed no increase in biomass production.

Switchgrass scenario Cost data for this scenario are based on data provided in an ISU Thesis entitled, "Yield and chemical composition of grass and legume species grown for maximum biomass production" (Lawlor, 1991). Where specific data were unavailable, ISU Extension publication Fm-1698

(Judd and Edwards, 1992) was used. For specific costs for this scenario refer to Table 6.

Income for this scenario is based on estimated yields of 10.3 dry metric tons of biomass/hectare/year (Anderson et al., 1991). Price per metric ton is based on DOE estimated price for biomass for energy at $40.00/dry metric ton (Wright, et al., 1989). No increase of biomass production was included for increasing biosolids application from 1X to 2X, based on Anderson et al. (1991), where an increased application of fertilizer showed no increase in biomass production.

Table 6. Cost data used for the switchgrass scenarios in the AAB alternatives

Cost item[b]		Assumed yield 10.3 dmt/hectare[a] Fixed	Variable
Establishment costs			
Tractors and equipment			$77.85
Seed @ $8.69/kg 7		$60.83	
Nitrogen @ $0.51/kg	34		17.34
Phosphorus @ $0.55/kg	70		38.50
Potassium @ $0.37/kg	70		25.90
Lime @ $16.32/t 2		32.64	
Application			6.42
Herbicide and application (0.56 kg 2,4-D)		10.82	
Chisel plow		$2.54	1.74
Double disk		5.58	4.45
Harrow (custom)			8.15
Drill planter (custom)			16.05
Preharvest labor @ $6.00/hr	6		36.00
Total		$8.12	$258.54

[a] Based on research results of average yield 10.3 dry metric ton/ha (dmt) when applying 140 kg of N/ha. Data from Agronomy & Agricultural Engineering Research Center - ISU, Ames. (Anderson et al., 1991).

[b]Based on data from Lawlor (1991), Duffy and Judd (1991), and Judd and Edwards (1992).

Table 6. Cont.

Annual Chemical, etc.			
Phosphorus @ $0.55/kg	35		19.25
Potassium @ $0.37/kg	20		7.40
Lime @ $16.32/t 1		16.32	
Application (custom)			6.42
Miscellaneous			
Interest on preharvest variable costs (8 mo. @ 12%)			8.03
Total			$57.42
Biosolids Application Vehicle			$204.52
Harvesting Costs: Large round bales (custom rates)			
Mower-conditioner			$19.27
Rake			7.78
Baling @ $1.16/t	9		10.44
Hauling (9 mt)		2.50	
Interest on harvesting variable costs (8 months @ 12%)			2.32
Harvest Labor			
6 hours @ $6.00/hr		36.00	–
Total		$36.00	$42.31
Land			
Cash rent		$247.10	–
Total fixed, variable			
Per hectare		$291.22	$640.64
Per metric ton		$29.12	$64.06
Total cost per hectare		$931.86	
Total cost metric ton		$93.19	

PNW and AEW were figured using a 4% real alternative rate of return for all scenarios using QUICK-SILVER, a Forestry investment analysis computer program. These values are given in Table 7 in the results and discussion section.

The next step to determine PNW and AEW for each of the three alternatives was to weight the PNW and AEW for all the scenarios. Weighting was determined by the proportion of area that a scenario occupied within the alternatives.

For the status quo alternative the two scenarios, corn following soybeans and soybeans following corn, would be used every other year. Thus each scenario's measures were multiplied by a 0.5 weighting value.

For the AAB alternatives, the SRWC system occupies one half of the total land area (based on the AAP). As a result, the SRWC scenarios economic measures were multiplied by a 0.5 weighting value.

The sorghum and switchgrass scenarios occupied equal portions of the last half (0.5) of the AAB alternatives. Thus, these cropping scenario's economic measures were multiplied by a 0.25 weighting value.

After the weighted discounted costs, incomes, PNW, and AEW were determined, the values for the scenarios within each alternative were added together to give total values for discounted costs, incomes, PNW, and AEW for the three alternatives. For economic results for the three alternatives, see Table 11 and Figures 10 and 11 in the results and discussion section.

CHAPTER V. RESULTS AND DISCUSSION

In this section, the results of the economic analysis for the economic criteria are presented and described. Then, the relative values for the other "questions of impact" for the ecological, political/institutional, and social areas of consideration are presented in the final matrix and described.

Economic results

Table 7 shows the discounted costs and incomes, PNW, and AEW for all scenarios at a real discount rate of 4%. The corn and soybeans scenarios are presented assuming a 1X (168 kg per hectare) biosolids application rate. Thus, comparisons between the status quo scenarios and the SRWC, sorghum, and switchgrass scenarios with 1X biosolids are most appropriate. This is because all scenarios are treated similarly for the biosolids cost input of $204.52 per hectare. It is clear for the AAB scenarios (SRWC, sorghum, and switchgrass) that increasing the biosolids application from 1X to 2X substantially increase scenario costs. Yields increase only for the first (1X) application of biosolids, because additional fertilizer above 168 kg/hectare has not been found to increase yields of these crops (Johnson et al., 1987; Anderson et al., 1991).

The relative rankings of the scenarios will be the same for the measures included in this table (discounted cost, incomes, PNW and AEW). As a result, the measure AEW will be compared for this discussion. AEW is a commonly-used measure which shows the net returns (or losses) from a long-term investment in yearly, time adjusted values. For this analysis, as mentioned, the analysis period was 21 years and a real alternative rate of return of 4% was used.

Table 7. Summary of discounted costs and incomes, present net worth, (PNW) and annual equivalent worth (AEW) for all scenarios in constant 1992 dollars per hectare ($/ha) at a 4% real discount rate

Scenario	Discounted **Costs**	Discounted **Income**	**PNW $/ha**	**AEW $/ha**
Corn following soybeans	-15,599	10,960	-4,640	-331
Soybeans following corn	-11,870	7,700	- 4,100	-292
SRWC 0X biosolids application	-7,143	3621	-3,521	-259
SRWC 1X biosolids application	-11,170	5,619	-5,551	-369
SRWC 2X biosolids application	-14,040	5,619	-8,420	-600
Sorghum 0X biosolids application	-9,785	8537	-1249	-89
Sorghum 1X biosolids application	-12,859	10,581	-2,279	-162
Sorghum 2X biosolids application	-15,933	10,581	-5,352	-382
Switchgrass 0X biosolids application	-6,200	3787	-2,413	-172
Switchgrass 1X biosolids application	-9,274	6,192	-3,082	-220
Switchgrass 2X biosolids application	-12,348	6192	-6156	-439

As can be seen in Table 7, all AEW values are negative. This is because of the relatively high yearly costs of $204.52 per hectare for the application of biosolids and $247.10 for land rent that were included in the analysis. These costs are included because they are actual costs incurred by the Ames WPCF. One might dispute the inclusion of the biosolids application given that it is a "necessary cost" associated with the disposal of municipal biosolids. However, because all the scenarios have been treated equally, the net effect of including it only shows the actual performance of the scenarios given actual costs incurred. If this cost were removed, the only profitable venture would be the sweet sorghum (1X) scenario because of very high expected yields of biomass.

No governmental subsidy programs have been considered throughout this analysis. Obviously, for the corn and soybean scenarios, governmental cost share makes the production of these crops profitable; otherwise, the city of Ames would not be using the system. Similar government programs for the AAB alternatives are available, but those opportunities will not be discussed in detail.

As shown in Table 7, the SRWC (1X) scenario costs the most on an annual basis, followed closely by the corn following soybeans scenario. The SRWC (1X) scenario is more costly because of high costs associated with planting and harvesting, given the relatively low yields per hectare per year when compared to the other crops, such as sweet sorghum. The reason the corn following soybeans scenario has the next most negative AEW is because this cropping system requires considerable inputs of fertilizer (commercial and biosolids) every year. Combined with the low prices paid for cereal grains, this makes the scenario more negative for AEW compared to the remaining scenarios.

Table 8 shows the weighted values for the discounted costs and incomes, PNW, and AEW for the three alternatives. Weighting was determined by the proportion of area that a scenario (tree or crop) occupied within the alternatives.

For the status quo alternative the two scenarios, corn following soybeans and soybeans following corn, would be used every other year. Thus, each scenario measure was multiplied by a 0.5 weighting value.

For the AAB alternatives, the SRWC system occupies one-half of the total land area (based on the AAP). As a result, the SRWC scenario economic measures were multiplied by a 0.5 weighting value.

The sorghum and switchgrass scenarios occupied equal portions of the last half (0.5) of the AAB alternatives. Thus, these cropping scenario measures were multiplied by a 0.25 weighting value.

After the weighting of discounted costs, incomes, PNW, and AEW, the values for the scenarios within each alternative were added together to give total values for discounted costs, incomes, PNW, and AEW for the three alternatives. For economic results for the three alternatives at a 4% real discount rate, see Table 11 and Figures 10 and 11.

Table 9 summarizes the PNW for all scenarios, with discount rate varying from 4% to 12%, at increments of 2%.

For additional economic results of individual cropping scenarios with variable biosolids applications, as well as summary tables of the status quo and AAB at 6% & 8% discount rates, refer to appendix C.

Table 8. Summary of weighted discounted costs and incomes, PNW, and AEW in constant 1992 $/ha for all scenarios

Scenario	Costs	Income	PNW	AEW
Corn following soybeans	-7,800	5,480	-2,320	-166
Soybeans following corn	-5,935	3,850	-2050	-145
SRWC 0X biosolids application	-3,571	1,811	-1,761	-130
SRWC 1X biosolids application	-5,585	2,801	-2,776	-185
SRWC 2X biosolids application	-7,020	2,810	-4,210	-300
Sorghum 0X biosolids application	-2,446	2,134	-312	-22
Sorghum 1X biosolids application	-3,215	2,645	-570	-41
Sorghum 2X biosolids application	-3,983	2,645	-1,338	-96
Switchgrass 0X biosolids application	-1,550	946	-603	-43
Switchgrass 1X biosolids application	-2,319	1,548	-771	-55
Switchgrass 2X biosolids application	-3,087	1,548	-1,539	-110

Table 9. Summary of PNW in constant 1992 $/ha for all scenarios, by real discount rate

Scenario	4 %	6 %	8 %	10 %	12 %
Corn following soybeans	-4,640	-3,940	-3,401	-2,979	-2,634
Soybeans following corn	-4,100	-3,482	-3,005	-2,632	-2,336
SRWC 0X biosolids application	-3,521	-3,194	-2,926	-2,707	-2,526
SRWC 1X biosolids application	-5,551	-4,965	-4,492	-4,106	-3,788
SRWC 2X biosolids application	-8,420	-7,371	-6,541	-5,875	-5,335
Sorghum 0X biosolids application	-1,249	-1,061	-916	-802	-712
Sorghum 1X biosolids application	-2,279	-1,935	-1,670	-1,463	-1,298
Sorghum 2X biosolids application	-5,352	-4,546	-3,924	-3,436	-3,049
Switchgrass 1X biosolids application	-3,082	-2,654	-2,322	-2,061	-1,854
Switchgrass 2X biosolids application	-6,156	-5,264	-4,575	-4,035	-3,605

Figure 8 shows a summary of PNW for all scenarios (1X biosolids application), with discount rate varying from 4% to 12%, at increments of 2%. The figure shows that the SRWC scenario has the most negative PNW at all interest rates. This is because, when compared to the other cropping scenarios, the SRWC (1X) scenario requires fairly high inputs and has relatively lower biomass yields. The sorghum (1X) cropping scenario has the best PNW value. This is because this system has fairly low inputs while having high biomass yields. The other cropping systems PNW's fall somewhere between these two cropping systems.

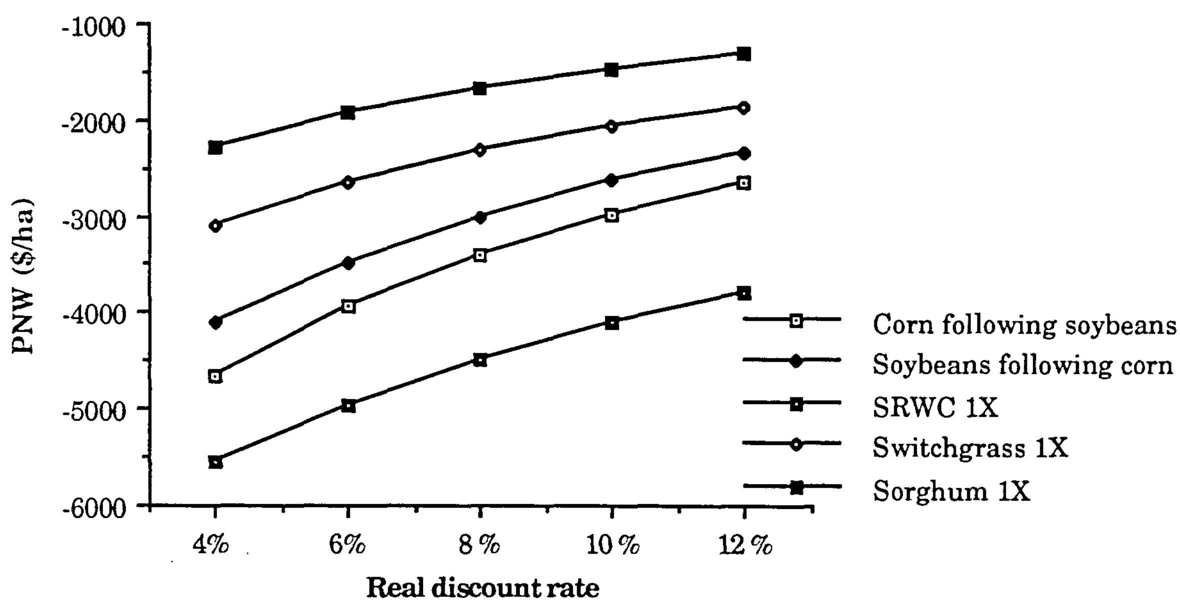

Figure 8. PNW for all cropping scenarios in constant 1992 $/ha with discount rates varying from 4% to 12% at increments of 2%

Table 10 summarizes the AEW from the QUICK-SILVER analysis for all scenarios, with discount rate varying from 4% to 12%, at increments of 2%. Figure 9 then shows graph of these results.

Table 10. Summary of annual equivalent worth (AEW) in constant 1992 $/ha for all scenarios by real discount rate

Scenario	4 %	6 %	8 %	10 %	12 %
Corn following Soybeans	-331	-335	-340	-344	-350
Soybeans following corn	-292	-296	-300	-304	-309
SRWC 0X biosolids application	-259	-278	-298	-318	-388
SRWC 1X biosolids application	-396	-422	-448	-475	-501
SRWC 2X biosolids application	-600	-627	-653	-679	-705
Switchgrass 0X biosolids application	-172	-177	-183	-189	-195
Switchgrass 1X biosolids application	-220	-226	-232	-238	-245
Switchgrass 2X biosolids application	-439	-447	-457	-467	-477
Sorghum 0X biosolids application	-89	-90	-91	-93	-94
Sorghum 1X biosolids application	-162	-165	-167	-169	-172
Sorghum 2X biosolids application	-382	-386	-392	-397	-403

Figure 9 shows a summary of AEW for all scenarios, with discount rate varying from 4% to 12%, at increments of 2%. The figure shows that the SRWC scenario has the most negative AEW at all interest rates. As with PNW, when compared to the other cropping scenarios, the SRWC (1X) scenario requires fairly high inputs given the lower biomass yields. The sorghum (1X) cropping scenario has the least negative PNW. This is because this system has fairly low inputs while having high biomass yields. The other cropping systems PNW's fall somewhere between these two cropping systems.

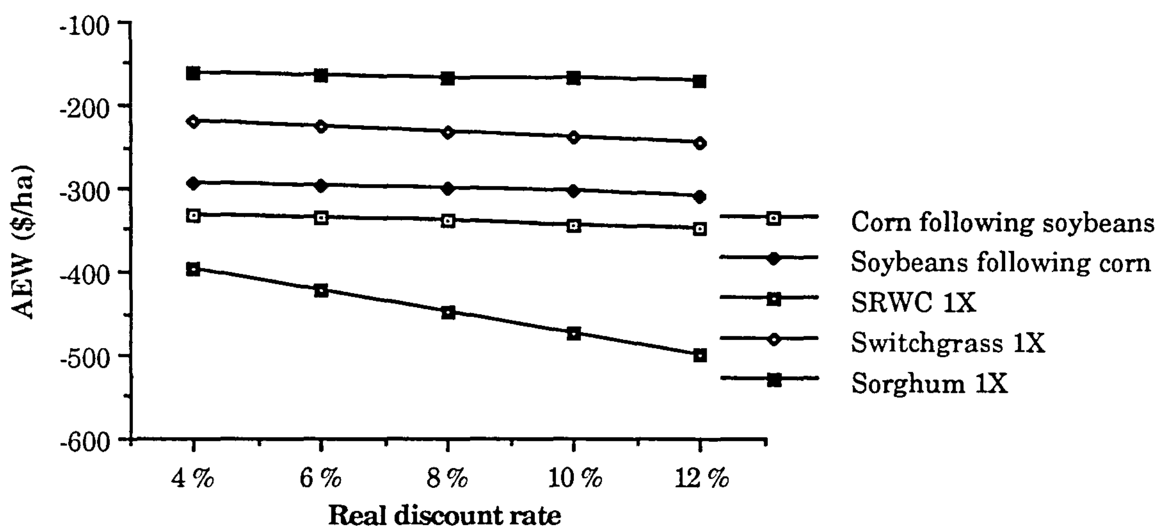

Figure 9. AEW for all cropping scenarios in constant 1992 $/ha with discount rates varying from 4% to 12% at increments of 2%

Table 11 shows a summary of the aggregate discounted costs and incomes, PNW, and AEW, as combined into alternatives, with a discount rate of 4%.

Table 11. Comparison of discounted costs and incomes, PNW, and AEW between status quo and alleycropping agroforestry for biomass (AAB) alternatives in constant 1992 $/ha at a 4% real discount rate

Alternative	Discounted **Costs**	Discounted **Income**	**PNW $/ha**	**AEW $/ha**
Status Quo	-13,735	9,330/ha	-4,370	-310
AAB 0X biosolids application	-7,568	4,891	-2,676	-195
AAB 1X biosolids application	-11,118	7,003	-4,116	-280
AAB 2X biosolids application	-14,090	7,002	-7,087	-505

Figure 10 shows a comparison of the PNW for the status quo alternative and the AAB alternative with 1X biosolids application and varying discount rates from 4% to 12%, by 2% increments. The graph shows that at lower discount rates, the status quo alternative has a more negative PNW than the AAB alternative. When the discount rate reaches ~7 1/2%, the lines of the two

Figure 11 shows a comparison of the AEW for the status quo alternative and the AAB alternative with 1X biosolids application and varying discount rates from 4% to 12% at 2% increments. The graph shows that at lower discount rates, the status quo alternative has a more negative AEW than the AAB alternative (the AAB alternative is better). When the discount rate reaches ~7 %, the lines for the two alternatives cross. Beyond that point the AAB alternative has a more negative AEW than does the status quo.

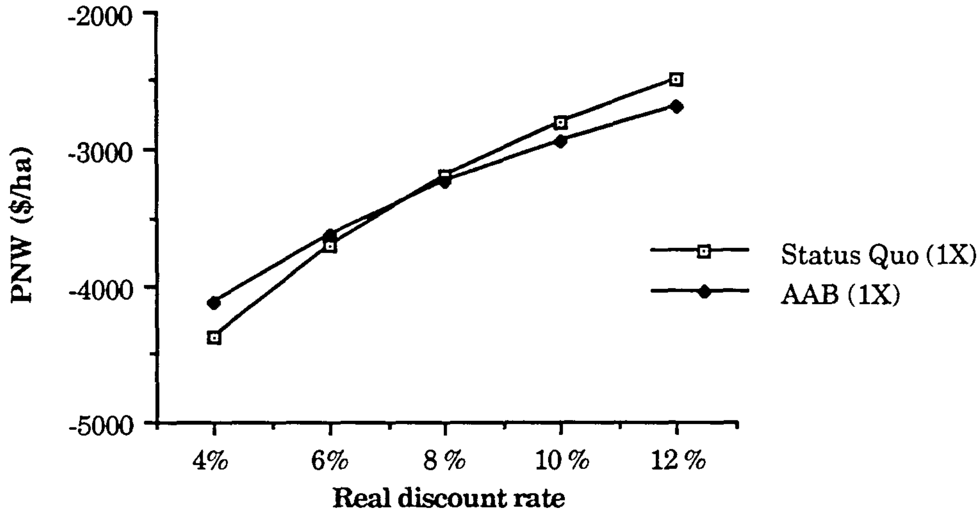

Figure 10. Comparison of PNW for status quo and AAB alternatives (1X biosolids application) in constant 1992 $/ha with discount rates varying from 4% to 12%, at increments of 2%

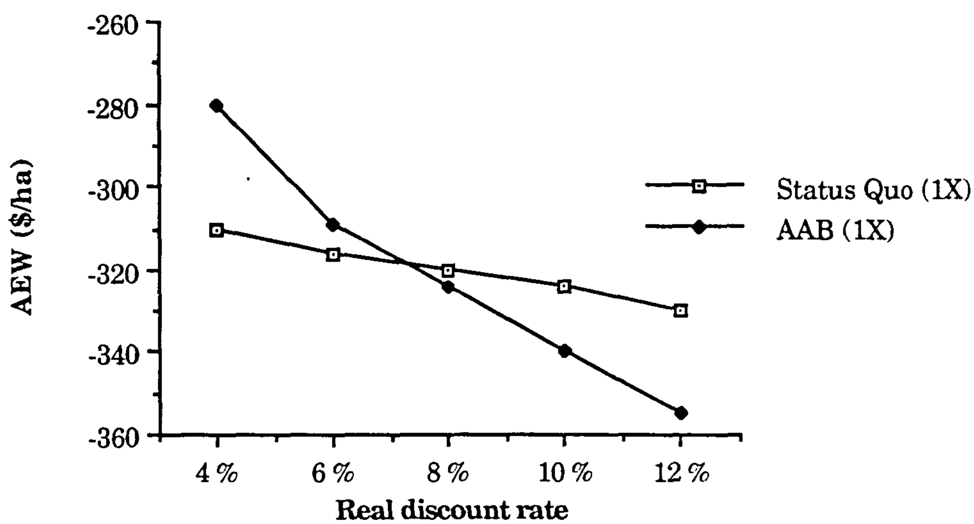

Figure 11. Comparison of AEW for status quo and AAB alternatives (1X biosolids application) in constant 1992 $/ha with discount rates varying from 4% to 12% at increments of 2%

alternatives cross. Beyond that point, the AAB alternative has a more negative PNW.

Table 14 is the matrix of all values for all areas of consideration. The only two alternatives that should be compared are the status quo and the AAB 1X. The AAB 2X alternative has been included in the matrix because the AAP has included this biosolids application as part of the research project. However, because of the extra cost and potential environmental impact for the additional biosolids, comparing it to the other alternatives, without adjustment, would not give an accurate analysis. Thus, the following discussion will highlight the difference between the status quo and the AAB 1X alternatives.

For the economic criteria (at a 4% real discount rate), the AAB (1X) alternative has the least negative PNW and AEW. The status quo alternative has the next-least negative PNW, and AEW, followed by the AAB (2X) alternative.

Ecological, political/institutional, and social areas of consideration

For the remaining areas of consideration - ecological, political/institutional, and social - the qualitative values for each alternative were developed by a heuristic process based on the literature review and the interviews that were conducted. As described earlier, quantifying these issues would be a very involved process, so a very limited measuring system was devised to evaluate the alternatives.

Ecological considerations The AAB (1X) receives the highest values for achievement of the questions in the ecological area. This alternative attains higher values for these questions because these issues are related to

Table 12. Matrix of economic values, and qualitative values for attainment of questions in ecological, political/institutional, and social areas of consideration

	ALTERNATIVES		
CRITERIA	Status Quo	AAB 1X	AAB 2X
Economic			
PNW	$ -4,730/ha	$ -4,116/ha	$ -7,087/ha
AEW	$ -310/ha	$ -280/ha	$ -505/ha
Ecological			
Minimization of heavy metals impact	low	medium	low
Minimization of nitrogen impact	low	high	medium
Wildlife enhancement	low	high	medium
Political/Institutional			
"in vogue" environmentally	low	high	medium
Tried & proven- similar projects nearby	high	low	low
Improve relations between arms of government	medium	medium	medium
Workable within institution	high	medium	medium
Social			
Health risks minimized	low	medium	low
Aesthetics improved	low	high	high
NIMBY issues minimized	medium	medium	low

concerns for minimizing potential health risks to humans, and to environmental degradation. Potential risks are linked to pollution associated with heavy metals and other contaminants, such as nitrogen, moving off-site through the movement of water. Movement of heavy metals and nitrogen can be reduced by cropping systems that provide year around ground cover (Higgins et al., 1982; Schultz et al., 1991). Thus, the AAB system receives higher "values" (or rankings) for the first two ecological concerns. The status quo receives lower values because this cropping system does not perform as well for these issues. The other benefit provided by both AAB systems is diversity in crops; thus they will enhance animal diversity (Schultz et al., 1991), which is not the case for the status quo. The AAB 2X system receives a lower value because there could be some negative impacts from too much biosolids.

Political/institutional considerations For this set of criteria, the status quo received higher values; however, the AAB 1X alternative received fairly high scores; on the other hand, each received higher values on different issues.

The status quo received high values for the criteria "tried and proven" (similar projects nearby) and "workable within the institution". These values were given simply because these issues highlight the current situation. At this time there are no problems with how biosolids are treated/disposed for the Ames WPCF, and there are plenty of other communities nearby that apply biosolids to agronomic crops (Ringelestein, 1992). For the "improve relations" criterion, it would be expected that there wouldn't necessarily be a better option available because the current relationship between the Ames WPCF and other arms of government is good (Ringelestein, 1992). For the "in vogue - environmentally" criterion the status quo received a low value because of concerns that, essentially, are highlighted by the ecological concerns (Hadwiger, 1992).

The AAB 1X alternative receives a high level of attainment for the "in vogue - environmentally" criterion. This is because the systems expected benefits fit well with the growing public concern for the environment (Hadwiger, 1992). For the criterion "improve relations between government" and "workable within institution" the AAB 1X alternative was given medium values. This is because it is not expected that the system would improve the institutional situation; however, it would likely not damage it either (Hadwiger, 1992). For the "tried and proven" criterion the AAB 1X received a low score, this is because there are, if any, only a few projects similar to the AAP project.

Social considerations For social considerations, the AAB 1X alternative receives higher values than the status quo. The AAB 1X alternative receives a high value for "aesthetics improved" because this alternative offers cropping diversity, so it should be readily accepted by the general public (Bultena, 1992). The AAB 1X receives a medium ranking for the "health risks minimized" criterion. This is because the issue is closely tied to ecological concerns, and because the AAB 1X provides better environmental protection from heavy metal and nitrogen contamination; thus health risks should be less. For the "NIMBY issues minimized" criterion, the AAB 1X alternative receives a medium value as does the status quo. This is because there seems, at this time, to be no problems arising with the current cropping system. As a result, the new cropping cropping system would not be expected to improve the situation.

The status quo receives a low value for minimizing health risks because there is question whether the cropping system offers acceptable environmental protection (Schultz, et al. 1991). For "aesthetics improved" this alternative also receives a low value. This is because a corn soybean crop rotation offers very little diversity to the Iowa landscape (Bultena, 1992; Schultz et al. 1991). Finally, the status quo seemingly does an adequate job of minimizing NIMBY issues.

CHAPTER VI. SUMMARY AND CONCLUSIONS

Based solely on the economic analysis in this thesis, assuming a 4% real alternative rate of return, the alleycropping agroforestry for biomass (AAB) system with 1X (168 kg/hectare) biosolids application rate is a better choice than using a rotation of corn and soybeans for the treatment/disposal of municipal treated biosolids. The AAB with 2X biosolids application is the least desirable choice based on the economic evaluation. The cost and income items in this analysis are based on best estimates available, including the actual cost of operating the sludge application vehicle.

Two questions about the economic analysis might arise. The first is whether or not the costs for biosolids application should be included. The second, asks why federal subsidies have not been included as a source of income.

In response to the first question, one might justifiably ignore the biosolids application cost given that the treatment/disposal of the biosolids is an unavoidable cost for municipalities. Given the limited treatment/disposal options available for Ames, it seems to be the only reasonable choice, because as pointed out by Ringelestein (1992), the only economically feasible options for biosolids disposal in Iowa is land application or landfilling. For the City of Ames, however, the landfilling option was eliminated with the closing of the City landfill when the Solid Waste Recovery Plant was put on-line for disposal of solid wastes. Thus, the only other option for biosolids treatment/disposal for the Ames would be to construct a dedicated biosolids disposal site that would be required to have all the precautionary measures needed for a hazardous waste disposal site. These facilities are very expensive to construct. Thus, for Ames, given current federal regulations, the only acceptable biosolids treatment/disposal option available is land application.

The cost concern is justifiable. However, the emphasis of this analysis was on comparing treatment/disposal alternatives. And, because all alternatives were treated equally for this cost, the alternatives were compared on a common basis.

The second question highlights another limitation of this thesis. It would have been more thorough to include, as an income, federal subsidies available for growing corn and soybeans and for the AAB cropping system. Although not specifically addressed, these issues have been given consideration. However, because of uncertainties associated with possible federal subsidies associated with SRWC for biomass systems, no subsidies were included.

In a general sense, government subsidies have been included in this analysis. This is because prices for products from both alternatives are being affected by government subsidies. Prices for cereal crops are kept artificially low by a variety of government programs. This point is highlighted by the results of this analysis that, when using strictly cost and income data, growing corn and soybeans is unprofitable on the average, even with the exclusion of the biosolids disposal cost.

Energy prices, on the other hand, are also being supported by government subsidies (Hubbard, 1991). So, the prices considered for biomass for energy are lower than the "real" prices. But, determining whether these price effects are the same as corn and soybeans subsidies, or how they affect a site-specific project, would be difficult.

Regardless, this analysis assumes that potential funding for both cropping systems would be available. Subsidies for the corn and soybean crops are provided through the crop/income support and set-aside program of the 1990 Food, Agriculture, Conservation, and Trade (FACT) Act. Subsidies for the AAB alternative might come under the Conservation Reserve Program (CRP), as well as through tax incentives provided by the State of Iowa for placing land in trees .

The second component of this analysis was to evaluate biosolids treatment/disposal options based on other considerations, including ecological, political/institutional, and social issues. Based on the relative, qualitative values presented in Table 14, the AAB 1X system is the better choice for the treatment/disposal of biosolids.

Primarily, the AAB system offers better ecological and social benefits than does the status quo. The status quo requires less change, so it fits better with a situation that would be change resistant. The AAB 2X alternative is a questionable endeavor based on the potential risks associated with putting "too much" biosolids on the crops. The reality of this concern, and the impact on plant growth and yield, should be investigated further. Overall, the AAB 1X system seems to be a better option for the land treatment/disposal of municipal biosolids for the City of Ames than is the status quo alternative.

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I wish also to thank the members of my program of study committee: Dr. Richard Schultz, and Dr. Lita Rule, who were both extremely supportive and a pleasure to work with, and Dr. Mack Shelley.

Dr. Jianbang Gan also deserves a special note of recognition for his unending selfless assistance and friendship.

Finally, I would like to thank my family for all the support they have provided over the many years of my education. But most importantly I would like to thank my wife Arlis and my son Devon, who have given me tremendous love and support throughout all of my endeavors.

APPENDIX A: QUICK-SILVER ANALYSIS

FORESTRY INVESTMENT ANALYSIS

TRANSACTIONS

>>> QUICK-SILVER <<<
FORESTRY DEPARTMENT
IOWA STATE UNIVERSITY

FILE-AAFSQC THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

CORN FOLLOWING SOYBEANS SCENARIO / 1X BIOSOLIDS APPLICATION
ANALYSIS FOR 1 HECTARE / 21 YEAR ANALYSIS PERIOD / CONSTANT COSTS
AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW

NO.	ACTIVITY TAX CLASS	FIRST YEAR	LAST YEAR	STEP YEARS	CURRENT VALUE ($/UNIT)	RATE OF CHANGE (%/YR.)	QUANTITY	UNITS (PRODUCT)
1	Annual Mgmt. ORDINARY EXPENSE	0	21	1	-1037.94	0.00	1.00	EACH
2	NON-TIM SALE ORDINARY INCOME	0	21	1	2.36	0.00	309.00	EACH OTHER PROD
3	YEAR MARKER YEAR MARKER	0	0	0	0.00	0.00	1.00	EACH

FORESTRY INVESTMENT ANALYSIS
FINANCIAL ANALYSIS RESULTS

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FORESTRY DEPARTMENT
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FILE-AAFSQC THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

CORN FOLLOWING SOYBEANS SCENARIO / 1X BIOSOLIDS APPLICATION
ANALYSIS FOR 1 HECTARE / 21 YEAR ANALYSIS PERIOD / CONSTANT COSTS
AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW

BEFORE TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	-15599	-13248	-11435	-10015	-8887
PRESENT VALUE (BENEFITS)	10960	9308	8034	7036	6244
PRESENT NET WORTH	-4640	-3940	-3401	-2979	-2643
BENEFIT/COST RATIO	0.70	0.70	0.70	0.70	0.70
ANNUAL EQUIVALENT VALUE	-331	-335	-340	-344	-350
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

AFTER TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	0	0	0	0	0
PRESENT VALUE (BENEFITS)	0	0	0	0	0
PRESENT NET WORTH	0	0	0	0	0
BENEFIT/COST RATIO	0.00	0.00	0.00	0.00	0.00
ANNUAL EQUIVALENT VALUE	0	0	0	0	0
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

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FORESTRY INVESTMENT ANALYSIS           >>>  QUICK-SILVER   <<<
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TRANSACTIONS                           IOWA STATE UNIVERSITY

FILE-AAFSQB  THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY:  ANDY SKADBERG     DATE:  7/2/92
=========================================================================
SOYBEANS FOLLOWING CORN SCENARIO / 1X BIOSOLIDS APPLICATION
ANALYSIS FOR 1 HECTARE / 21 YEAR ANALYSIS PERIOD / CONSTANT COSTS
AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW

=========================================================================

                      FIRST  LAST  STEP  CURRENT  RATE OF
NO. ACTIVITY           YEAR  YEAR YEARS   VALUE    CHANGE QUANTITY UNITS
     TAX CLASS                           ($/UNIT)  (%/YR.)         (PRODUCT)
-------------------------------------------------------------------------
  1 Annual Mgmt.        0    21     1  -789.80     0.00     1.00 EACH
     ORDINARY EXPENSE
  2 NON-TIM SALE        0    21     1     5.50     0.00    94.00 EACH
     ORDINARY INCOME                                             OTHER PROD
  3 YEAR MARKER         0     0     0     0.00     0.00     1.00 EACH
     YEAR MARKER
=========================================================================
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FORESTRY INVESTMENT ANALYSIS
FINANCIAL ANALYSIS RESULTS

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FILE-AAFSQB THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

SOYBEANS FOLLOWING CORN SCENARIO / 1X BIOSOLIDS APPLICATION
ANALYSIS FOR 1 HECTARE / 21 YEAR ANALYSIS PERIOD / CONSTANT COSTS AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW

BEFORE TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	-11870	-10081	-8701	-7621	-6762
PRESENT VALUE (BENEFITS)	7770	6599	5696	4988	4427
PRESENT NET WORTH	-4100	-3482	-3005	-2632	-2336
BENEFIT/COST RATIO	0.65	0.65	0.65	0.65	0.65
ANNUAL EQUIVALENT VALUE	-292	-296	-300	-304	-309
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

AFTER TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	0	0	0	0	0
PRESENT VALUE (BENEFITS)	0	0	0	0	0
PRESENT NET WORTH	0	0	0	0	0
BENEFIT/COST RATIO	0.00	0.00	0.00	0.00	0.00
ANNUAL EQUIVALENT VALUE	0	0	0	0	0
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

FORESTRY INVESTMENT ANALYSIS >>> QUICK-SILVER <<<
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FILE-AAFPB1 THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

SRWC SCENARIO WITH HERBICIDE AND MECHANICAL WEED CONTROL AND 0X BIOSOLIDS APPLICATION / ANALYSIS FOR A 1 HA SRWC SYSTEM OF POPULUS 8X4 FT. SPACING / ROTATION LENGTH 7 YRS AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW

NO.	ACTIVITY TAX CLASS	FIRST YEAR	LAST YEAR	STEP YEARS	CURRENT VALUE ($/UNIT)	RATE OF CHANGE (%/YR.)	QUANTITY	UNITS (PRODUCT)
1	SITE PREP REFORESTATION COST	0	0	0	-39.80	0.00	1.00	EACH
2	HERBICIDE ORDINARY EXPENSE	0	1	1	-109.90	0.00	1.00	EACH
3	PLANTING REFORESTATION COST	0	0	0	-835.50	0.00	1.00	EACH
4	LAND RENT ORDINARY EXPENSE	1	20	1	-247.10	0.00	1.00	EACH
5	HARVEST COST SALE EXPENSE	7	7	0	-26.00	0.00	69.19	TONS
6	FINAL H'VEST TIMBER SALE	7	7	0	40.00	0.00	69.19	TONS BIOMASS
7	HERBICIDE ORDINARY EXPENSE	7	8	1	-109.90	0.00	1.00	EACH
8	HERBICIDE ORDINARY EXPENSE	14	15	1	-109.90	0.00	1.00	EACH
9	YEAR MARKER YEAR MARKER	0	0	0	0.00	0.00	1.00	EACH

FORESTRY INVESTMENT ANALYSIS

FINANCIAL ANALYSIS RESULTS

>>> QUICK-SILVER <<<
FORESTRY DEPARTMENT
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FILE-AAFPB1 THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

SRWC SCENARIO WITH HERBICIDE AND MECHANICAL WEED CONTROL AND 0X BIOSOLIDS APPLICATION / ANALYSIS FOR A 1 HA SRWC SYSTEM OF POPULUS 8X4 FT. SPACING / ROTATION LENGTH 7 YRS AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW

BEFORE TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	-7232.44	-6112.14	-5268.90	-4622.22	-4117.37
PRESENT VALUE (BENEFITS)	3621.34	2858.27	2302.14	1887.71	1572.14
PRESENT NET WORTH	-3611.10	-3253.87	-2966.76	-2734.51	-2545.23
BENEFIT/COST RATIO	0.50	0.47	0.44	0.41	0.38
ANNUAL EQUIVALENT VALUE	-265.71	-283.69	-302.17	-321.19	-340.75
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

AFTER TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	0.00	0.00	0.00	0.00	0.00
PRESENT VALUE (BENEFITS)	0.00	0.00	0.00	0.00	0.00
PRESENT NET WORTH	0.00	0.00	0.00	0.00	0.00
BENEFIT/COST RATIO	0.00	0.00	0.00	0.00	0.00
ANNUAL EQUIVALENT VALUE	0.00	0.00	0.00	0.00	0.00
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

FORESTRY INVESTMENT ANALYSIS >>> QUICK-SILVER <<<
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FILE-AAFPB2 THESIS AMES A
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

SRWC SCENARIO WITH HERBICIDE AND MECHANICAL WEED CONTROL AND 1X BIOSOLIDS APPLICATION / ANALYSIS FOR A 1 HA SRWC SYSTEM OF POPULUS 8X4 FT. SPACING / ROTATION LENGTH 7 YRS AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW

NO.	ACTIVITY / TAX CLASS	FIRST YEAR	LAST YEAR	STEP YEARS	CURRENT VALUE ($/UNIT)	RATE OF CHANGE (%/YR.)	QUANTITY	UNITS (PRODUCT)
1	SITE PREP REFORESTATION COST	0	0	0	-39.80	0.00	1.00	EACH
2	HERBICIDE ORDINARY EXPENSE	0	1	1	-109.90	0.00	1.00	EACH
3	PLANTING REFORESTATION COST	0	0	0	-835.50	0.00	1.00	EACH
4	LAND RENT ORDINARY EXPENSE	1	20	1	-247.10	0.00	1.00	EACH
5	HARVEST COST SALE EXPENSE	7	7	0	-26.00	0.00	69.19	TONS
6	FINAL H'VEST TIMBER SALE	7	7	0	40.00	0.00	69.19	TONS BIOMASS
7	FINAL H'VEST TIMBER SALE	14	21	7	40.00	0.00	86.49	TONS BIOMASS
8	HARVEST COST SALE EXPENSE	14	21	7	-25.00	0.00	86.46	TONS
9	TRANSPORT ORDINARY EXPENSE	1	21	1	-204.52	0.00	1.00	EACH
10	HERBICIDE ORDINARY EXPENSE	7	8	1	-109.90	0.00	1.00	EACH
11	HERBICIDE ORDINARY EXPENSE	14	15	1	-109.90	0.00	1.00	EACH
12	YEAR MARKER YEAR MARKER	0	0	0	0.00	0.00	1.00	EACH

FORESTRY INVESTMENT ANALYSIS

FINANCIAL ANALYSIS RESULTS

>>> QUICK-SILVER <<<
FORESTRY DEPARTMENT
IOWA STATE UNIVERSITY

FILE-AAFPB2 THESIS AMES A
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

SRWC SCENARIO WITH HERBICIDE AND MECHANICAL WEED CONTROL AND 1X
BIOSOLIDS APPLICATION / ANALYSIS FOR A 1 HA SRWC SYSTEM OF POPULUS
8X4 FT. SPACING / ROTATION LENGTH 7 YRS
AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW

BEFORE TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	-11170	-9354	-7972	-6905	-6068
PRESENT VALUE (BENEFITS)	5619	4388	3480	2799	2280
PRESENT NET WORTH	-5551	-4965	-4492	-4106	-3788
BENEFIT/COST RATIO	0.50	0.47	0.44	0.41	0.38
ANNUAL EQUIVALENT VALUE	-396	-422	-448	-475	-501
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

AFTER TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	0	0	0	0	0
PRESENT VALUE (BENEFITS)	0	0	0	0	0
PRESENT NET WORTH	0	0	0	0	0
BENEFIT/COST RATIO	0.00	0.00	0.00	0.00	0.00
ANNUAL EQUIVALENT VALUE	0	0	0	0	0
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

FORESTRY INVESTMENT ANALYSIS　　　>>> QUICK-SILVER <<<
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FILE-AAFPB3 THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

SRWC SCENARIO WITH HERBICIDE AND MECHANICAL WEED CONTROL AND 2X BIOSOLIDS APPLICATION / ANALYSIS FOR A 1 HA SRWC SYSTEM OF POPULUS 8X4 FT. SPACING / ROTATION LENGTH 7 YRS--3 ROTATIONS / CONSTANT COSTS AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW

NO.	ACTIVITY / TAX CLASS	FIRST YEAR	LAST YEAR	STEP YEARS	CURRENT VALUE ($/UNIT)	RATE OF CHANGE (%/YR.)	QUANTITY	UNITS (PRODUCT)
1	SITE PREP REFORESTATION COST	0	0	0	-39.80	0.00	1.00	EACH
2	HERBICIDE ORDINARY EXPENSE	0	1	1	-109.90	0.00	1.00	EACH
3	PLANTING REFORESTATION COST	0	0	0	-835.50	0.00	1.00	EACH
4	LAND RENT ORDINARY EXPENSE	1	20	1	-247.10	0.00	1.00	EACH
5	HARVEST COST SALE EXPENSE	7	7	0	-26.00	0.00	69.19	TONS
6	FINAL H'VEST TIMBER SALE	7	7	0	40.00	0.00	69.19	TONS BIOMASS
7	FINAL H'VEST TIMBER SALE	14	21	7	40.00	0.00	86.49	TONS BIOMASS
8	HARVEST COST SALE EXPENSE	14	21	7	-25.00	0.00	86.46	TONS
9	TRANSPORT ORDINARY EXPENSE	1	21	1	-409.04	0.00	1.00	EACH
10	HERBICIDE ORDINARY EXPENSE	7	8	1	-109.90	0.00	1.00	EACH
11	HERBICIDE ORDINARY EXPENSE	14	15	1	-109.90	0.00	1.00	EACH
12	YEAR MARKER YEAR MARKER	0	0	0	0.00	0.00	1.00	EACH

FORESTRY INVESTMENT ANALYSIS

FINANCIAL ANALYSIS RESULTS

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FILE-AAFPB3 THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

SRWC SCENARIO WITH HERBICIDE AND MECHANICAL WEED CONTROL AND 2X BIOSOLIDS APPLICATION / ANALYSIS FOR A 1 HA SRWC SYSTEM OF POPULUS 8X4 FT. SPACING / ROTATION LENGTH 7 YRS--3 ROTATIONS / CONSTANT COSTS AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW

BEFORE TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	-14040	-11760	-10021	-8674	-7615
PRESENT VALUE (BENEFITS)	5619	4388	3480	2799	2280
PRESENT NET WORTH	-8420	-7371	-6541	-5875	-5335
BENEFIT/COST RATIO	0.40	0.37	0.35	0.32	0.30
ANNUAL EQUIVALENT VALUE	-600	-627	-653	-679	-705
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

AFTER TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	0	0	0	0	0
PRESENT VALUE (BENEFITS)	0	0	0	0	0
PRESENT NET WORTH	0	0	0	0	0
BENEFIT/COST RATIO	0.00	0.00	0.00	0.00	0.00
ANNUAL EQUIVALENT VALUE	0	0	0	0	0
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

FORESTRY INVESTMENT ANALYSIS >>> QUICK-SILVER <<<

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TRANSACTIONS

FILE-AAFPSOO THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

CONTINUOUS SWEET SORGHUM SCENARIO / 0X BIOSOLIDS APPLICATION
ANALYSIS FOR 1 HECTARE / 21 YEAR ANALYSIS PERIOD / CONSTANT COSTS AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW
YIELD 14.2 DRY METRIC TONS/HECTARE

NO.	ACTIVITY TAX CLASS	FIRST YEAR	LAST YEAR	STEP YEARS	CURRENT VALUE ($/UNIT)	RATE OF CHANGE (%/YR.)	QUANTITY	UNITS (PRODUCT)
1	Annual Mgmt. ORDINARY EXPENSE	0	21	1	-651.10	0.00	1.00	EACH
2	NON-TIM SALE ORDINARY INCOME	0	21	1	40.00	0.00	14.20	EACH OTHER PROD
3	YEAR MARKER YEAR MARKER	0	0	0	0.00	0.00	1.00	EACH

FORESTRY INVESTMENT ANALYSIS
FINANCIAL ANALYSIS RESULTS

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FILE-AAFPS00 THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

CONTINUOUS SWEET SORGHUM SCENARIO / 0X BIOSOLIDS APPLICATION
ANALYSIS FOR 1 HECTARE / 21 YEAR ANALYSIS PERIOD / CONSTANT COSTS
AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW
YIELD 14.2 DRY METRIC TONS/HECTARE

BEFORE TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	-9785.49	-8310.69	-7173.04	-6282.26	-5574.72
PRESENT VALUE (BENEFITS)	8536.57	7250.00	6257.54	5480.46	4863.22
PRESENT NET WORTH	-1248.92	-1060.69	-915.50	-801.81	-711.50
BENEFIT/COST RATIO	0.87	0.87	0.87	0.87	0.87
ANNUAL EQUIVALENT VALUE	-89.02	-90.16	-91.40	-92.71	-94.09
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

AFTER TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	0.00	0.00	0.00	0.00	0.00
PRESENT VALUE (BENEFITS)	0.00	0.00	0.00	0.00	0.00
PRESENT NET WORTH	0.00	0.00	0.00	0.00	0.00
BENEFIT/COST RATIO	0.00	0.00	0.00	0.00	0.00
ANNUAL EQUIVALENT VALUE	0.00	0.00	0.00	0.00	0.00
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

FORESTRY INVESTMENT ANALYSIS

TRANSACTIONS

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FILE-AAFPSO1 THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

CONTINUOUS SWEET SORGHUM SCENARIO / 1X BIOSOLIDS APPLICATION
ANALYSIS FOR 1 HECTARE / 21 YEAR ANALYSIS PERIOD / CONSTANT COSTS
AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW
YIELD 17.6 DRY METRIC TONS/HECTARE

NO.	ACTIVITY TAX CLASS	FIRST YEAR	LAST YEAR	STEP YEARS	CURRENT VALUE ($/UNIT)	RATE OF CHANGE (%/YR.)	QUANTITY	UNITS (PRODUCT)
1	Annual Mgmt. ORDINARY EXPENSE	0	21	1	-855.62	0.00	1.00	EACH
2	NON-TIM SALE ORDINARY INCOME	0	21	1	40.00	0.00	17.60	EACH OTHER PROD
3	YEAR MARKER YEAR MARKER	0	0	0	0.00	0.00	1.00	EACH

FORESTRY INVESTMENT ANALYSIS

FINANCIAL ANALYSIS RESULTS

>>> QUICK-SILVER <<<
FORESTRY DEPARTMENT
IOWA STATE UNIVERSITY

FILE-AAFPSO1 THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

CONTINUOUS SWEET SORGHUM SCENARIO / 1X BIOSOLIDS APPLICATION
ANALYSIS FOR 1 HECTARE / 21 YEAR ANALYSIS PERIOD / CONSTANT COSTS
AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW
YIELD 17.6 DRY METRIC TONS/HECTARE

BEFORE TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	-12859	-10921	-9426	-8256	-7326
PRESENT VALUE (BENEFITS)	10581	8986	7756	6793	6028
PRESENT NET WORTH	-2279	-1935	-1670	-1463	-1298
BENEFIT/COST RATIO	0.82	0.82	0.82	0.82	0.82
ANNUAL EQUIVALENT VALUE	-162	-165	-167	-169	-172
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

AFTER TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	0	0	0	0	0
PRESENT VALUE (BENEFITS)	0	0	0	0	0
PRESENT NET WORTH	0	0	0	0	0
BENEFIT/COST RATIO	0.00	0.00	0.00	0.00	0.00
ANNUAL EQUIVALENT VALUE	0	0	0	0	0
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

FORESTRY INVESTMENT ANALYSIS

TRANSACTIONS

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FILE-AAFPSO2 THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

CONTINUOUS SWEET SORGHUM SCENARIO / 2X BIOSOLIDS APPLICATION
ANALYSIS FOR 1 HECTARE / 21 YEAR ANALYSIS PERIOD / CONSTANT COSTS
AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW
YIELD 17.6 DRY METRIC TONS/HECTARE

NO.	ACTIVITY TAX CLASS	FIRST YEAR	LAST YEAR	STEP YEARS	CURRENT VALUE ($/UNIT)	RATE OF CHANGE (%/YR.)	QUANTITY	UNITS (PRODUCT)
1	Annual Mgmt. ORDINARY EXPENSE	0	21	1	-1060.14	0.00	1.00	EACH
2	NON-TIM SALE ORDINARY INCOME	0	21	1	40.00	0.00	17.60	EACH OTHER PROD
3	YEAR MARKER YEAR MARKER	0	0	0	0.00	0.00	1.00	EACH

FORESTRY INVESTMENT ANALYSIS

FINANCIAL ANALYSIS RESULTS

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FILE-AAFPSO2 THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

CONTINUOUS SWEET SORGHUM SCENARIO / 2X BIOSOLIDS APPLICATION
ANALYSIS FOR 1 HECTARE / 21 YEAR ANALYSIS PERIOD / CONSTANT COSTS AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW
YIELD 17.6 DRY METRIC TONS/HECTARE

BEFORE TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	-15933	-13532	-11679	-10229	-9077
PRESENT VALUE (BENEFITS)	10581	8986	7756	6793	6028
PRESENT NET WORTH	-5352	-4546	-3924	-3436	-3049
BENEFIT/COST RATIO	0.66	0.66	0.66	0.66	0.66
ANNUAL EQUIVALENT VALUE	-382	-386	-392	-397	-403
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

AFTER TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	0	0	0	0	0
PRESENT VALUE (BENEFITS)	0	0	0	0	0
PRESENT NET WORTH	0	0	0	0	0
BENEFIT/COST RATIO	0.00	0.00	0.00	0.00	0.00
ANNUAL EQUIVALENT VALUE	0	0	0	0	0
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

FORESTRY INVESTMENT ANALYSIS

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FILE-AAFPSW0 THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

SWITCHGRASS SCENARIO / 0X BIOSOLIDS APPLICATION
ANALYSIS FOR 1 HECTARE / 21 YEAR ANALYSIS PERIOD / CONSTANT COSTS AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW
YIELD 6.3 DRY METRIC TONS/HECTARE

NO.	ACTIVITY TAX CLASS	FIRST YEAR	LAST YEAR	STEP YEARS	CURRENT VALUE ($/UNIT)	RATE OF CHANGE (%/YR.)	QUANTITY	UNITS (PRODUCT)
1	SITE PREP REFORESTATION COST	0	10	10	-266.66	0.00	1.00	EACH
2	Annual Mgmt. ORDINARY EXPENSE	0	21	1	-382.83	0.00	1.00	EACH
3	NON-TIM SALE ORDINARY INCOME	0	21	1	40.00	0.00	6.30	EACH OTHER PROD
4	YEAR MARKER YEAR MARKER	0	0	0	0.00	0.00	0.00	EACH

FORESTRY INVESTMENT ANALYSIS >>> QUICK-SILVER <<<

FINANCIAL ANALYSIS RESULTS

FORESTRY DEPARTMENT
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FILE-AAFPSWO THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

SWITCHGRASS SCENARIO / 0X BIOSOLIDS APPLICATION
ANALYSIS FOR 1 HECTARE / 21 YEAR ANALYSIS PERIOD / CONSTANT COSTS AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW
YIELD 6.3 DRY METRIC TONS/HECTARE

BEFORE TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	-6200.42	-5302.03	-4607.74	-4063.28	-3630.31
PRESENT VALUE (BENEFITS)	3787.35	3216.55	2776.23	2431.47	2157.62
PRESENT NET WORTH	-2413.07	-2085.49	-1831.50	-1631.81	-1472.68
BENEFIT/COST RATIO	0.61	0.61	0.60	0.60	0.59
ANNUAL EQUIVALENT VALUE	-172.00	-177.28	-182.84	-188.68	-194.75
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

AFTER TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	0.00	0.00	0.00	0.00	0.00
PRESENT VALUE (BENEFITS)	0.00	0.00	0.00	0.00	0.00
PRESENT NET WORTH	0.00	0.00	0.00	0.00	0.00
BENEFIT/COST RATIO	0.00	0.00	0.00	0.00	0.00
ANNUAL EQUIVALENT VALUE	0.00	0.00	0.00	0.00	0.00
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

FORESTRY INVESTMENT ANALYSIS

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FORESTRY DEPARTMENT
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FILE-AAFPSW1 THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

SWITCHGRASS SCENARIO / 1X BIOSOLIDS APPLICATION
ANALYSIS FOR 1 HECTARE / 21 YEAR ANALYSIS PERIOD / CONSTANT COSTS AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW
YIELD 10.3 DRY METRIC TONS/HECTARE

NO.	ACTIVITY / TAX CLASS	FIRST YEAR	LAST YEAR	STEP YEARS	CURRENT VALUE ($/UNIT)	RATE OF CHANGE (%/YR.)	QUANTITY	UNITS (PRODUCT)
1	SITE PREP REFORESTATION COST	0	10	10	-266.66	0.00	1.00	EACH
2	Annual Mgmt. ORDINARY EXPENSE	0	21	1	-587.35	0.00	1.00	EACH
3	NON-TIM SALE ORDINARY INCOME	0	21	1	40.00	0.00	10.30	EACH OTHER PROD
4	YEAR MARKER YEAR MARKER	0	0	0	0.00	0.00	0.00	EACH

FORESTRY INVESTMENT ANALYSIS
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FORESTRY DEPARTMENT
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FILE-AAFPSW1 THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

SWITCHGRASS SCENARIO / 1X BIOSOLIDS APPLICATION
ANALYSIS FOR 1 HECTARE / 21 YEAR ANALYSIS PERIOD / CONSTANT COSTS AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW
YIELD 10.3 DRY METRIC TONS/HECTARE

BEFORE TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	-9274.19	-7912.55	-6860.89	-6036.63	-5381.41
PRESENT VALUE (BENEFITS)	6192.02	5258.80	4538.92	3975.26	3527.55
PRESENT NET WORTH	-3082.17	-2653.74	-2321.97	-2061.37	-1853.86
BENEFIT/COST RATIO	0.67	0.66	0.66	0.66	0.66
ANNUAL EQUIVALENT VALUE	-219.70	-225.58	-231.81	-238.34	-245.16
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

AFTER TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	0.00	0.00	0.00	0.00	0.00
PRESENT VALUE (BENEFITS)	0.00	0.00	0.00	0.00	0.00
PRESENT NET WORTH	0.00	0.00	0.00	0.00	0.00
BENEFIT/COST RATIO	0.00	0.00	0.00	0.00	0.00
ANNUAL EQUIVALENT VALUE	0.00	0.00	0.00	0.00	0.00
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

FORESTRY INVESTMENT ANALYSIS

TRANSACTIONS

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FILE-AAFPSW2 THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

SWITCHGRASS SCENARIO / 2X BIOSOLIDS APPLICATION
ANALYSIS FOR 1 HECTARE / 21 YEAR ANALYSIS PERIOD / CONSTANT COSTS
AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW
YIELD 10.3 DRY METRIC TONS/HECTARE

NO.	ACTIVITY TAX CLASS	FIRST YEAR	LAST YEAR	STEP YEARS	CURRENT VALUE ($/UNIT)	RATE OF CHANGE (%/YR.)	QUANTITY	UNITS (PRODUCT)
1	SITE PREP REFORESTATION COST	0	10	10	-266.66	0.00	1.00	EACH
2	Annual Mgmt. ORDINARY EXPENSE	0	21	1	-791.87	0.00	1.00	EACH
3	NON-TIM SALE ORDINARY INCOME	0	21	1	40.00	0.00	10.30	EACH OTHER PROD
4	YEAR MARKER YEAR MARKER	0	0	0	0.00	0.00	0.00	EACH

FORESTRY INVESTMENT ANALYSIS

FINANCIAL ANALYSIS RESULTS

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FORESTRY DEPARTMENT
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FILE-AAFPSW2 THESIS AMES AGROFORESTRY PROJECT ANALYSIS
PREPARED BY: ANDY SKADBERG DATE: 7/2/92

SWITCHGRASS SCENARIO / 2X BIOSOLIDS APPLICATION
ANALYSIS FOR 1 HECTARE / 21 YEAR ANALYSIS PERIOD / CONSTANT COSTS AND REVENUES ASSUMED / BEFORE TAX DISCOUNTED CASH FLOW
YIELD 10.3 DRY METRIC TONS/HECTARE

BEFORE TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	-12348	-10523	-9114	-8010	-7133
PRESENT VALUE (BENEFITS)	6192	5259	4539	3975	3528
PRESENT NET WORTH	-6156	-5264	-4575	-4035	-3605
BENEFIT/COST RATIO	0.50	0.50	0.50	0.50	0.49
ANNUAL EQUIVALENT VALUE	-439	-447	-457	-467	-477
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

AFTER TAXES

DISCOUNT RATE (%)	4.000	6.000	8.000	10.000	12.000
PRESENT VALUE (COSTS)	0	0	0	0	0
PRESENT VALUE (BENEFITS)	0	0	0	0	0
PRESENT NET WORTH	0	0	0	0	0
BENEFIT/COST RATIO	0.00	0.00	0.00	0.00	0.00
ANNUAL EQUIVALENT VALUE	0	0	0	0	0
COMPOSITE RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99
INTERNAL RATE OF RETURN	-99.99	-99.99	-99.99	-99.99	-99.99

-99.99 = VALUE NOT CALCULATED

APPENDIX B: OVERVIEW OF TWO PRIVATE INDUSTRIAL SRWC FIBER OPERATIONS LOCATED IN OREGON AND WASHINGTON

Overview of two private, industrial SRWC fiber operations located in Oregon and Washington.

SRWC systems are a developing technology, and large scale operations are being implemented in the private sector. In order for university researchers to keep up with these changing technologies, it will be necessary to conduct research and development of these systems and their related activities. In the Northwestern United States (Washington and Oregon) there are two commercial, production scale, operations of SRWC systems currently underway. These two projects are located in two climatically different sites in the region. One project is located near the Pacific Coast, and the other is on the east side of the Cascade Mountains.

The first SRWC operation is being developed by the James River Corporation in Clatskanie, Oregon which is nearby one of their paper production facilities. The second, more recently established operation is being undertaken by the Boise Cascade Corporation in Eastern Washington near Wallula, Washington--the location of one of their paper mills. For both operations, the product is fiber and not woody biomass for energy.

The differences between the operations, functionally, is related to water management. In Eastern Washington (Lower Columbia River Basin) the problem is not enough rainfall (about 15.2 cm/year), thus the Boise Cascade operation is highly dependent on irrigation. The James River project, on the other hand, has a very different water management problem with which to deal. Located in the Lower Columbia River Basin, on the Columbia River about 80 km from where the river empties into the Pacific Ocean, the water management involves removing excess water from the plantation site. The plantation site has an elevation that varies from ~1 m above to ~1 m below sea level. This land ordinarily would not be available for crop production. The government, however, built an embankment and an extensive drainage canal system back in the early part of the century to convert the land to crop production.

The purposes of visiting these two "fiber farms" were 1) to see the actual operations, 2) to record photographic information, and 3) to gain some insights into each companies production scheme, especially regarding plantation establishment and cultural management.

OVERVIEW OF OPERATIONS

James River--Lower Columbia River Fiber Farm

The James River (JR) Project was initiated in about 1980. Currently they have 3,238 - 3,642 ha in production. In the past six years they have planted 486 ha of hybrid poplar (*Populus deltoides*) each year. Last year was the first year that they harvested trees from the plantation. The fiber is being used for white paper production at their mill that is located near the plantation. As mentioned, the productivity of the land is highly dependent on the channel system that was built.

Planting is done by hand, by migrant workers. They plant 30.5 cm unrooted cuttings. Spacing between the rows and trees in the row is (3.7 m x 1.8 m), respectively. Currently, there is no need for use of fertilizer. Harvesting and chipping occurs on-site by special equipment suited to the site.

Rotation length for their operation is 6 years and they expect to get 13-18 dry metric tons of chips/ha at the end of the rotation. Seventy percent of the harvested biomass ends up as clean chips and the rest is used as hog fuel. JR manages 4,452 ha total in the area. However, about 20% of the land is un-farmable because of environmental conditions. They currently use 3-5 *Populus* clones. Since establishment of the operation they have planted 30 different *Populus* clones, however, they have conducted research with some 3000-4000 different clones.

Boise Cascade Cottonwood Project

The Boise Cascade (BC) Project began planting trees for production in 1991. They currently have about 1,214 ha of trees planted. When the project is fully established they plan to have a total of 7,285 ha in production with 1,214 ha being harvested and planted each year.

Adequate water for tree growth is their biggest challenge. Thus, irrigation is crucial for their operation. Currently, they use two different irrigation systems. The first is located on their lease agreement lands and consists of a flood, or rill irrigation system. This irrigation system was established during the 1920's. This system has not performed as well as expected, thus these fields will likely be eliminated from their operation.

The other system being utilized is drip irrigation. For this system, each row of trees has a long plastic sprinkler line that is placed adjacent to the tree row. Water emitters are spaced at regular intervals (1.8 m for their operation) along the line. During planting, one tree is planted by each emitter. Because of this design, each tree receives a regulated amount of water. If fertilizer is needed, it is placed directly into the irrigation system. Currently they are using about 44-57 kg of nitrogen per ha. Spacing for their plantation is 3.7 m x 1.8 m.

Production is expected to be ~18 dry metric tons of wood chips/ha at the end of the rotation. BC is very interested in clonal development, but being a younger operation, they are still developing the clonal research and development.

SIMILARITIES BETWEEN PROJECTS AND A DECISION MAKING FRAMEWORK

The similarities between the two operations are considerable. The production and research for the two projects is the same. Production strategies of the two operations are similar, because they both treat trees as an agronomic crop. They are growing hybrid poplar on a short rotation (6 years) and applying intensive management.

Management styles differ between the two operations primarily because of the different styles of the managers, and the different demands of the area (including climatic and political) where they are in production. A summary of the operations is provided by a five point overview provided by Don Rice the Supervisor of the James River Project.

These statements are considerations Mr. Don Rice (Project Supervisor) made while establishing the James River SRWC system.

1) Are the sites chosen for growing the trees appropriate for growing these

trees?

a) Can the area can be effectively managed?

b) Will trees grow well in this area?

2) The system is dependent on the development of improved genetic material.

a) That the improved clones improve overall productivity

b) That the clones used will better survive the rigors of the environment where they are being grown.

3) The systems are agricultural crop production systems rather than forestry operations.

a) Manipulate the environment to optimize productivity

e.g. Managing water or other limiting factors

b) Use inputs such as pesticides and fertilizer when necessary

4) Harvesting techniques are unique to the operation and are designed to handle a unique product and situation.

a) Production is taking place on flat ground unlike much forestry

b) Material is essentially symmetric and homogeneous in size and makeup.

5) That the systems are sensible environmentally

a) Conservation of soil

b) Consider impacts to wildlife

This outline describes the operational and decision-making framework for the James River operation precisely, as spelled out by the Project Supervisor. Boise Cascade, however, is only into their second year of planting so, actual production was not seen (from planting to harvesting), on the other hand, some experimental plots had been harvested and appeared to be very similar to the James River operation. Thus, it seems, that this overview will suffice for a description Boise Cascade operation as well.

DIFFERENCES BETWEEN PROJECTS

Differences between the two operations arise from the geographical location of the sites and the socio-political environment where the plantations are located. The Boise Cascade plantation is located in an area that can be described as desert. The James River operation is located in a much more ecologically diverse area. And, the JR plantation seemed have much more complex biological management problems than the Boise Cascade Project. Additionally, the population in Eastern Washington is small in comparison to the area where the JR Project is located (about equidistant between Portland, Oregon and Seattle, Washington). This difference in population creates dramatic differences in the kinds of issues that arise socially, and politically, for the managers.

JAMES RIVER CORP. Lower Columbia River Fiber Farm

Because the Northwest Pacific coast receives considerable rainfall, the area is heavily forested and has a relatively diverse ecology of plants and animals. Many plantation management problems arise from this diversity. For example, the James River management team must employ a full-time beaver trapper to deal with the damage caused by the resident beaver population. Also, for the 20% of their un-farmable property, they have developed wildlife management areas. This wildlife management plan has arisen from a need to manage the wildlife in the area, but also there is a real problem dealing with some closely linked political issues. These issues are discussed later.

Other problems that arise from having more species of plants and animals are increased numbers of crop pests. Insect populations rise and fall from one year to the next. James River has been experimenting with different chemical or natural pest controls. Each solution works to an extent, but they always are tied to other problems. For example, they have been experimenting with using cover crops to reduce weed competition. This management practice worked relatively well for controlling weeds, but the resulting explosion in the vole population has become a bigger problem. These are is just one example of the many operational problems facing the JR plantation.

The more difficult problems seem to arise from public-governmental pressures to run an environmentally safe operation. Situated in the area where the heated, spotted owl controversy is happening, the political climate in the area can be described as volatile. The project manager said that he probably spends 80% of his time dealing with these issues. Groups that place demands on him are adjacent landowners, private/environmental groups, and governmental bureaucrats. Many of these outside interests have different issues that they focus on. To deal with the variety of issues, the project supervisor has established a network of special interest groups and economic development cooperators that cooperate in developing strategies for problem solving.

Another source of difficulty for the James River operations is the unique nature of their project. To highlight this aspect of the project is the fact that JR pays about twice the market rate ($160-$185/ha) to lease the land they use. The land owners were seemingly unwilling to lease the land without substantial enticement because of the "risky" nature of the new cropping system.

After observing all of the added difficulties and expense of an operation like this, one might expect that the project's future is somewhat tentative. Surprisingly, the opposite is true. The SRWC system is proving to be productive enough that James River is talking about expanding the cottonwood operation. This is because of the consistent quality of the material that is being produced, and the high productivity of the operation.

BOISE CASCADE Cottonwood Project

The ecological and socio-political situation at the Boise Cascade operation is dramatically different than at James River. BC does have management problems like pest and weed control, but, at this point they seem to be less problematic. They are, however, experimenting with different management techniques to deal with the problems they do have. For example, as the establishment of the operation progresses, they have been testing different herbicides and cover crops to deal with weed competition. They also are manipulating planting techniques to minimize costs while optimizing survival of the trees. The first year plantings were done with a modified asparagus planter. With this system they had survival of about 94%. Spacing of the trees, however, was not as consistent as they would like for optimizing their drip irrigation system. Thus, they they contracted an engineer to build a new planting machine. This planter, when built, will "feel" the irrigation line, then as it passes an emitter along the irrigation line, it will immediately push an unrooted cutting into the ground.

The management questions being faced are typical of any agricultural operation. . However, it seems that, because of the ecological setting, Boise Cascade has fewer and less complex biological problems to deal with--at least initially.

Socio-political problems at this point in time seem to be non-existent. This Eastern Washington area is accustomed to agricultural production and to growing trees in plantations (primarily fruit trees). And, there seems to be no special interest groups that are questioning the development of the SRWC system. It may happen that, after a few years in production, outside interest groups might take notice of the operation and start raising issues. Nonetheless, at this point in time, the socio-political climate for BC is essentially sedate.

The operation manager is considering environmental concerns and issues as the plantations are being established and managed. He has recognized that growing tall trees in this region will definitely diversify the environment and, as a result, there should be an increase in wildlife in the immediate vicinity of their plantations (as compared to the annual crops previously grown).

The challenges facing the Boise Cascade operation are more related to economics (getting water to the trees) than to environmental or socio-political issues. By far their greatest expense is for irrigation. Delivering water to the field can cost between $123 and $407/ha, annually. Installing the drip irrigation system runs from $1730 to $2471/ha. The specific cost is determined by the depth to the water table and the distance for distribution to the fields. These costs would be prohibitive to an SRWC operation in Iowa. Boise Cascade is very optimistic about their Cottonwood Project and they are already considering expanding operations.

NEED FOR RESEARCH

From the visits to these two large scale commercial operations it is clear that SRWC systems have tremendous potential. This is true even with the risks associated with each project. An outside observer might expect that the economic, social, and political pressures would stifle optimism for the projects. The opposite is true. Even facing the tremendous economic costs (as with Boise Cascade) and special interest pressure (as with James River), both operations are "running full-speed ahead." This suggests to the researchers at Iowa State that SRWC systems can succeed.

The JR & BC SRWC systems seem to be profitable. These two large corporations are willing to invest millions of dollars into operational scale projects. Obviously, both companies have researched SRWC. Unfortunately their information is not available to the public. Considering these facts, it seems that there is a real need to conduct research on SRWC systems and to make the findings available to the public.

CONCLUSIONS

These new SRWC technologies should be especially appealing to states such as Iowa with ~76 cm of annual precipitation and highly productive soils. As state economies falter on limited markets, diversification seems a necessity. SRWC systems offer some biologic diversity, as well as offering other environmental benefits. Thus these "technologies" should be appealing to states that have monocultures of one or two agricultural crops. And, in states that has significant potential for groundwater contamination, economically productive and environmentally beneficial solutions are needed. However, before we can wholeheartedly promote these new technologies, we must first study them.

SRWC technologies offer a variety of economic and environmental benefits . Thus, for Iowa, SRWC systems might provide some small solutions to a few problems. Then, with the development of a group of small solutions, the answers to our bigger environmental and economic problems will be solved by a well-orchestrated combination of these solutions.

APPENDIX C: ADDITIONAL ECONOMIC RESULTS FOR CROPPING SCENARIOS AND ALTERNATIVES

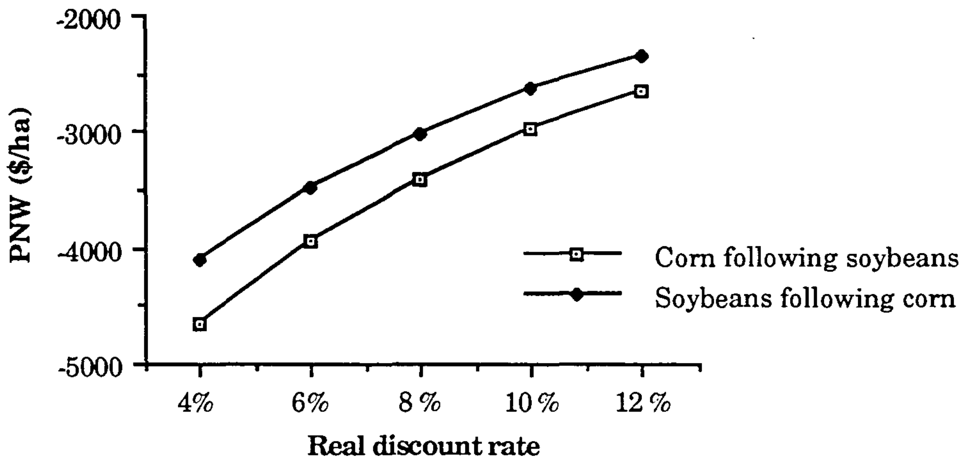

Figure 12. Present net worth for status quo scenarios, (biosolids application rates assumed 1X) by discount rate.

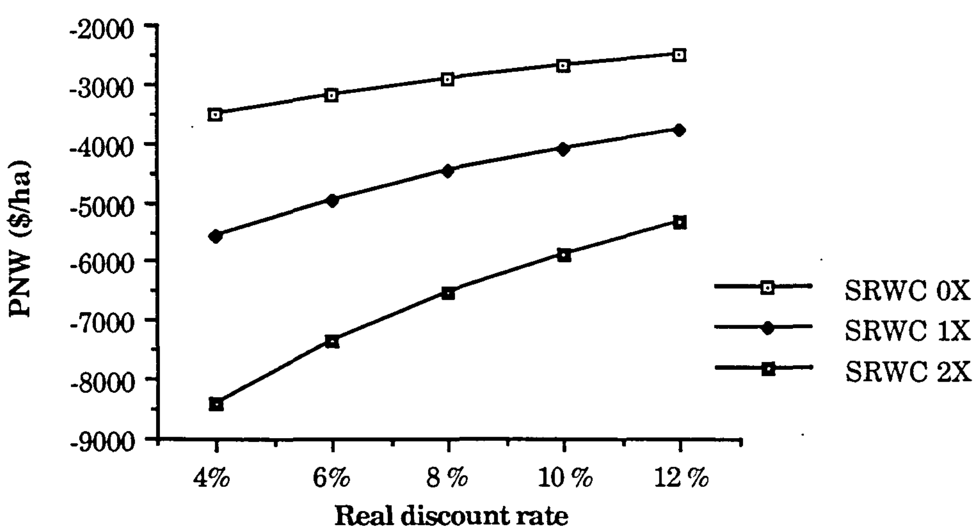

Figure 13. Present net worth for SRWC scenarios, (biosolids application rates 0X, 1X, and 2X) by discount rate.

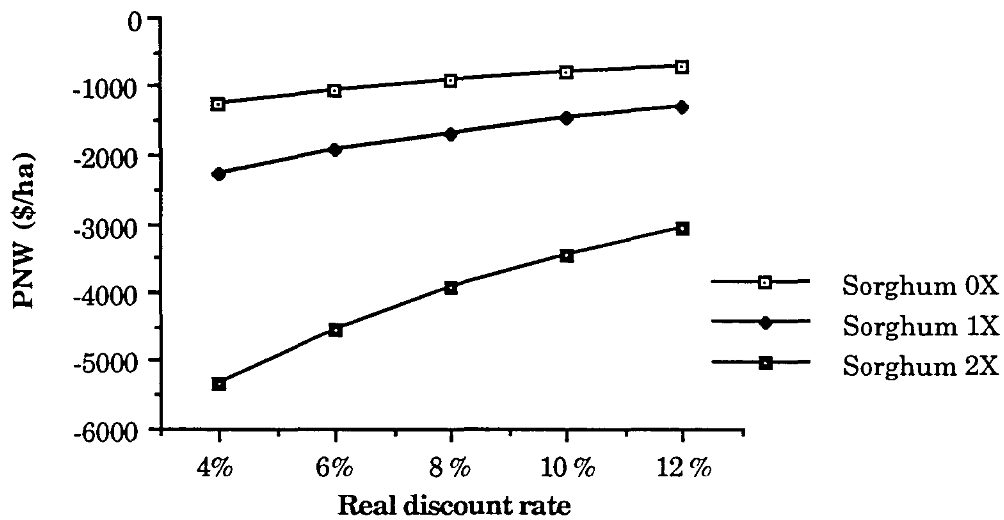

Figure 14. Present net worth for sorghum scenarios, (biosolids application rates 0X, 1X, and 2X) by discount rate.

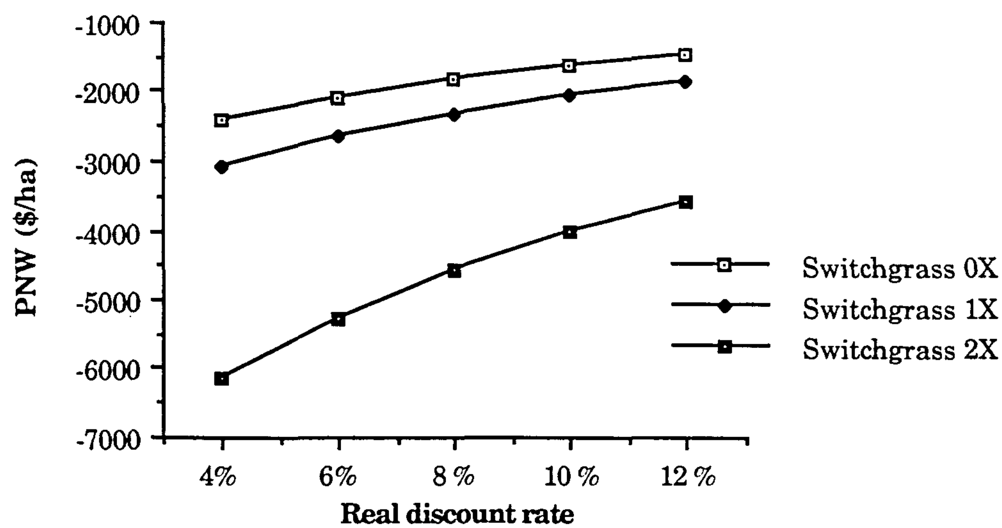

Figure 15. Present net worth for switchgrass scenarios, (biosolids application rates 0X, 1X, and 2X) by discount rate.

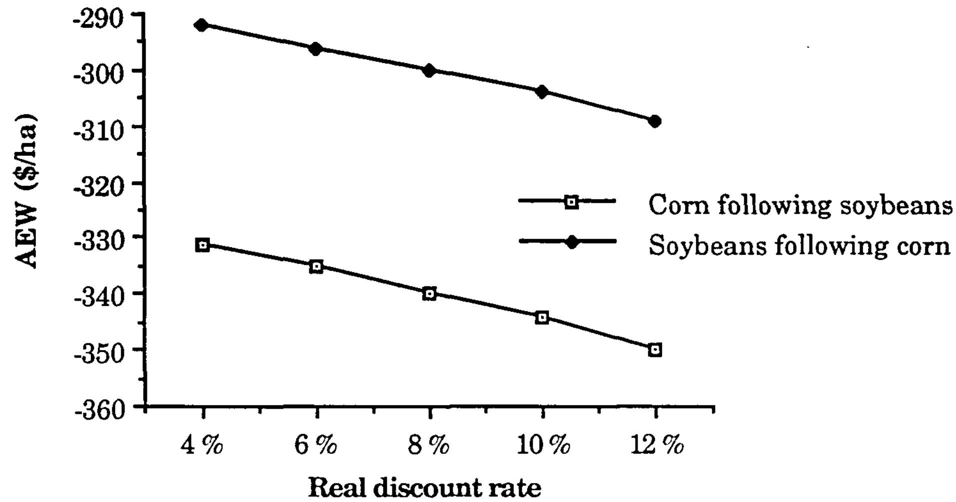

Figure 16. Annual equivalent worth for status quo scenarios, (biosolids application rate assumed at 1X) by discount rate.

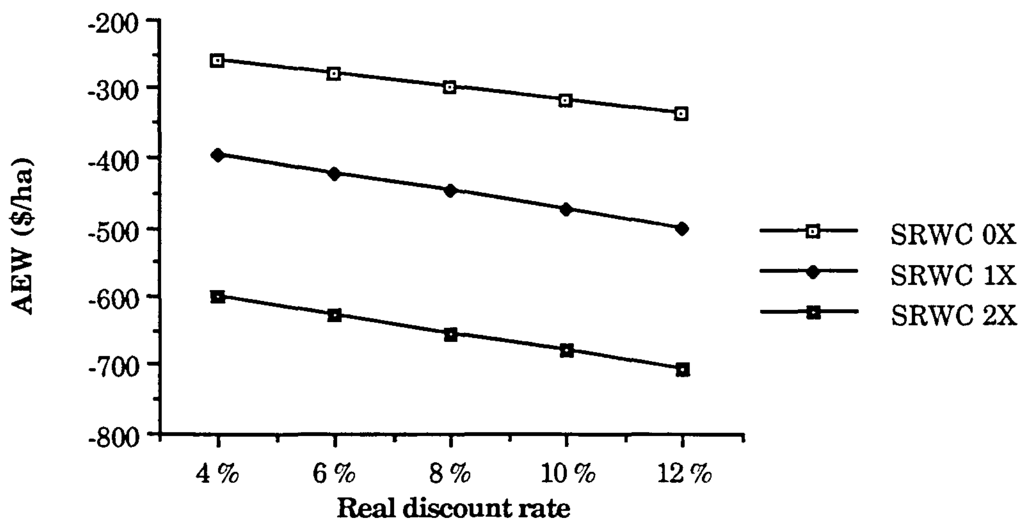

Figure 17. Annual equivalent worth for SRWC scenarios, (biosolids application rates 0X, 1X, and 2X) by discount rate.

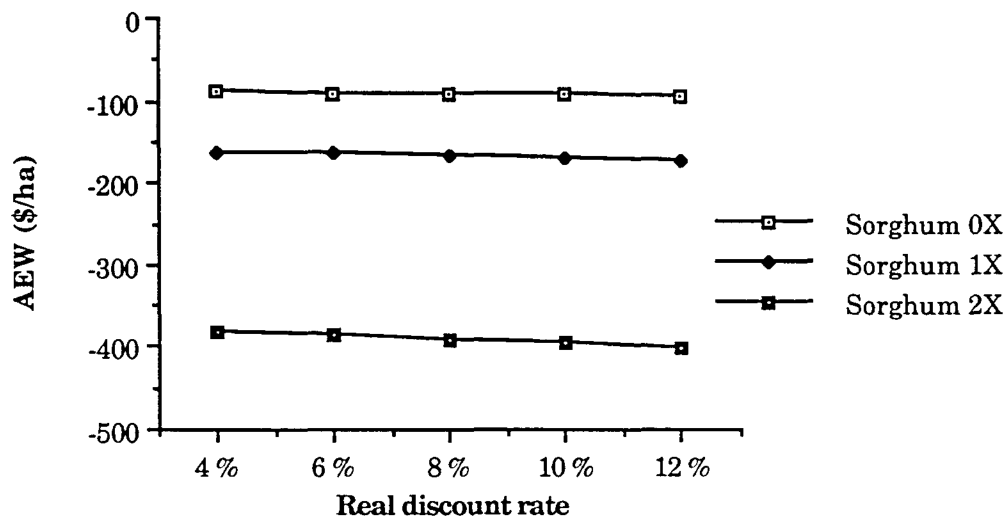

Figure 18. Annual equivalent worth for sorghum scenarios, (biosolids application rates 0X, 1X, and 2X) by discount rates.

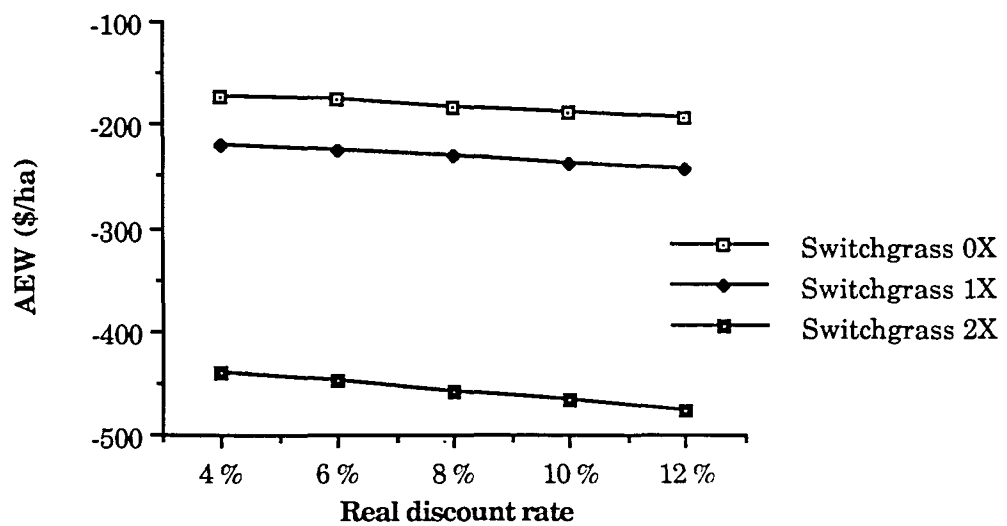

Figure 19. Annual equivalent worth for switchgrass scenarios, (biosolids application rates 0X, 1X, and 2X) by discount rate.

Table 13. Comparison of discounted costs and incomes, PNW, and AEW between status quo and alleycropping agroforestry for biomass (AAB) alternatives in constant 1992 $/ha at a 6% real discount rate

Alternative	Discounted Costs	Discounted Income	PNW $/ha	AEW $/ha
Status Quo	-11,665	7,954	-3,711	-316
AAB 0X biosolids application	-6,429	4,046	-2,383	-206
AAB 1X biosolids application	-9,385	5,755	-3630	-309
AAB 2X biosolids application	-11,894	5,755	-6,138	-522

Table 14. Comparison of discounted costs and incomes, PNW, and AEW between status quo and alleycropping agroforestry for biomass (AAB) alternatives in constant 1992 $/ha at an 8% real discount rate

Alternative	Discounted Costs	Discounted Income	PNW $/ha	AEW $/ha
Status Quo	-10,068	6,865	-3,203	-320
AAB 0X biosolids application	-5,559	3,410	-2,150	-218
AAB 1X biosolids application	-8,058	4,814	-3,244	-324
AAB 2X biosolids application	-10,209	4814	-5,395	-539